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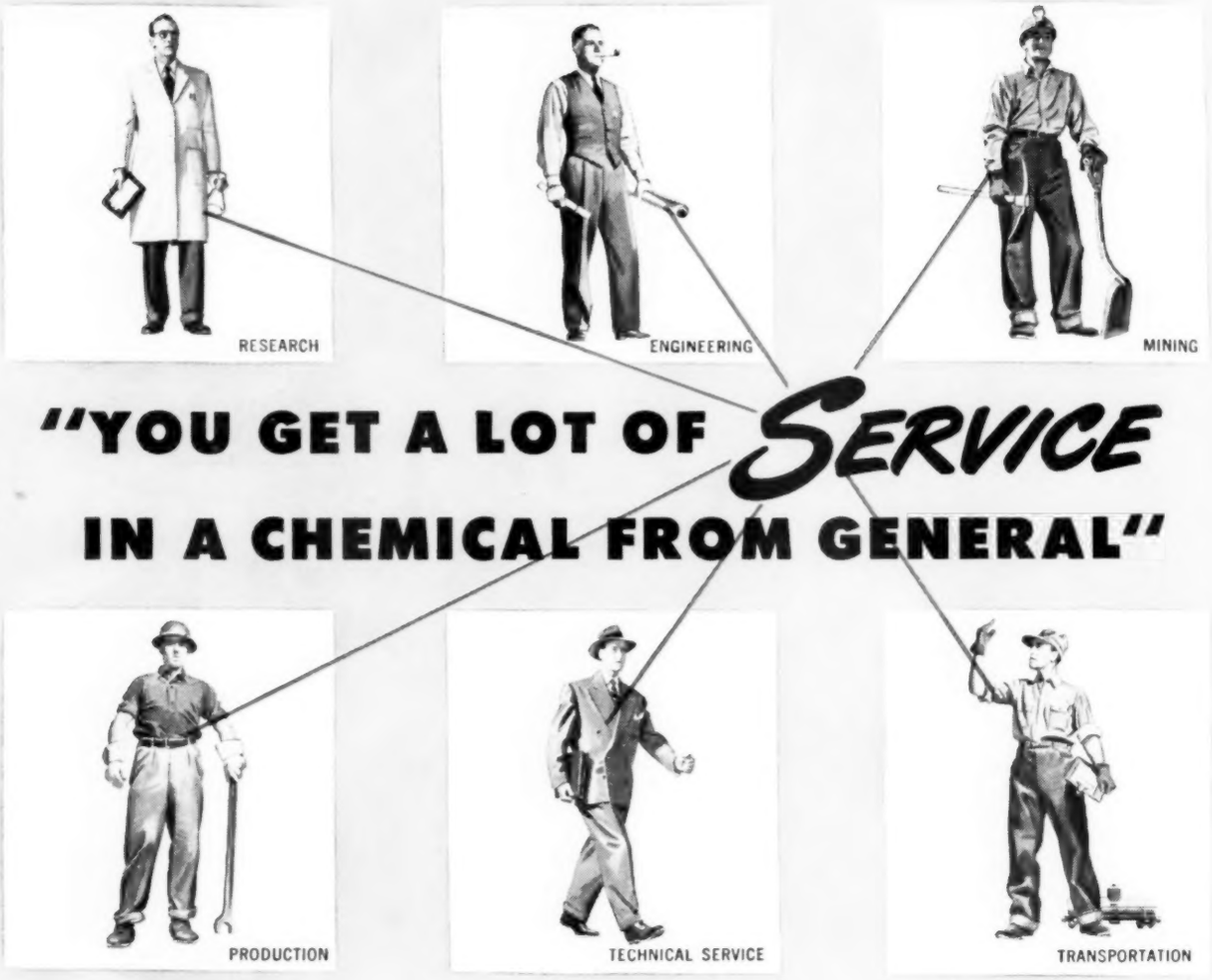

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COVER PHOTO

The new, improved M-9 gas mask featured by the soldier on the left is compared to its predecessor, the M4-10A1-6. In March the Chemical Corps invited bids on the production of 175,000 of the new light-weight masks. It is noted that the air purifying canister is attached to the cheek, eliminating the need for a hose. Either right or left hand models are available, with large, medium and small facepieces.

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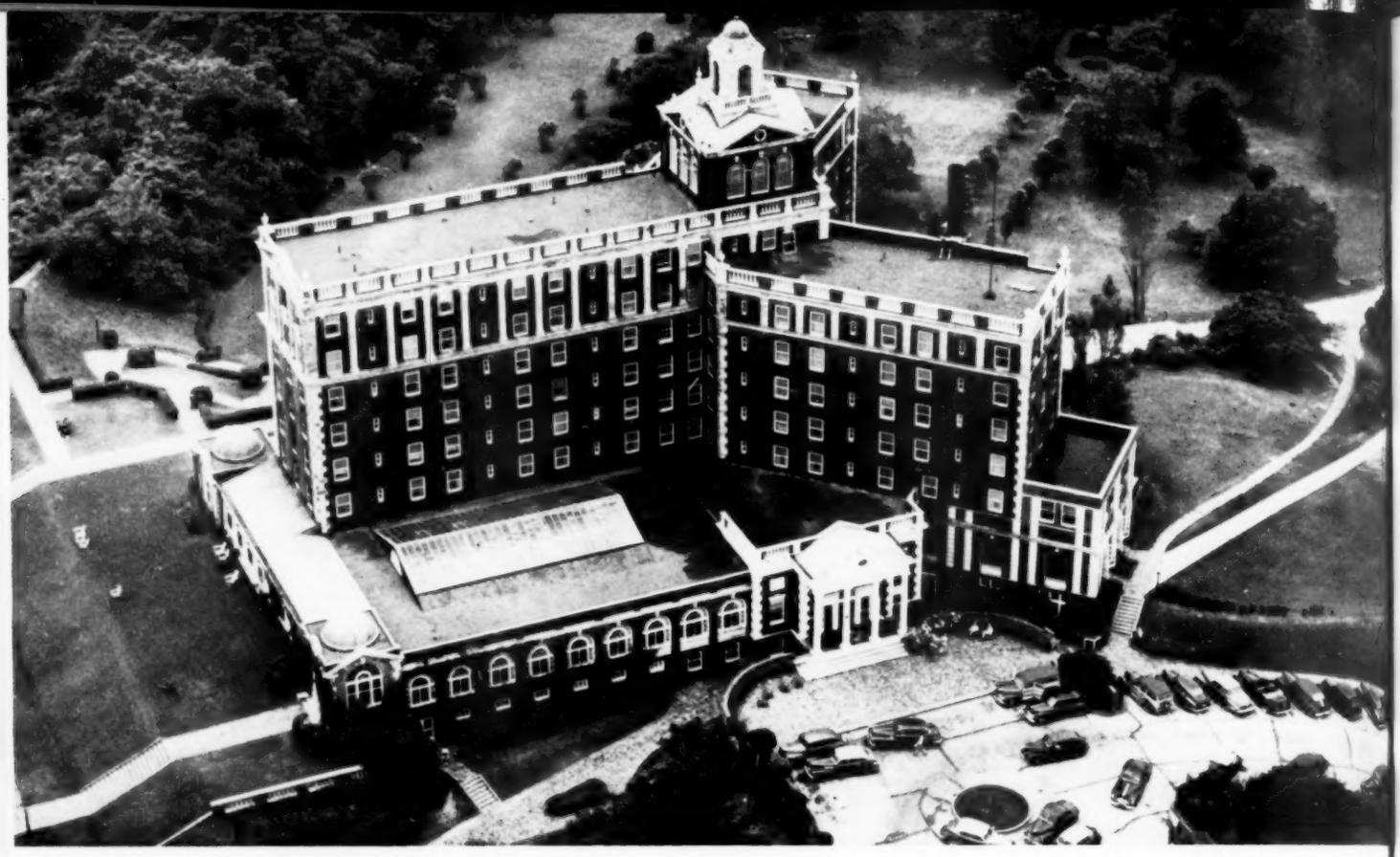


GENERAL COUPLAND
U. S. Air Force

GENERAL McAULIFFE
U. S. Army

ANNUAL MEETING HEADQUARTERS

The Cavalier Hotel

VIRGINIA BEACH

ADMIRAL SNACKENBERG
U. S. Navy

AFCA's GUESTS OF HONOR

Prediction !!!

IT'LL BE AFCA'S BEST—

1950 ANNUAL MEETING—VIRGINIA BEACH

THE PROGRAM

Thursday, June 1

9:00—Registration, Cavalier Hotel.
5:30 p.m. to 6:30 p.m.—Cocktail Party.
6:30 p.m. to 8:00 p.m.—Directors' Dinner.
8:00 p.m.—Board of Directors Meeting.

Friday, June 2

7:30 a.m. to 8:30 a.m.—Breakfast, Cavalier Hotel.
8:30 a.m. to 9:00 a.m.—Bus transportation to Naval Base.
9:00 a.m. to 10:00 a.m.—Directed tour of Naval Base.
10:00 a.m. to 12:00 a.m.—Annual Meeting, Base Theater.
12:00 noon to 1:30 p.m.—Luncheon, Officer Club.
1:30 p.m. to 3.00 p.m.—Guided tour of Battleship Missouri.
3:00 p.m. to 5:00 p.m.—Fire Prevention School—demonstration.
7:00 p.m. to 7:30 p.m.—Cocktail party, Cavalier Hotel.
7:30 p.m. to 9:00 p.m.—Banquet.

Saturday, June 3

8:00 a.m.—Breakfast and departure from Annual Meeting.

JUNE 1-2-3

In support of the March *News* statement that plans for AFCA's Annual Meeting looked excellent, last-minute information divulged by committeemen completing the schedule for the Virginia Beach meeting support the earlier claim—and moreso!

Highlighting the program as guests of the Association are representatives of the Defense Department, all of whom have a special interest in the Armed Forces Chemical Association. These top-ranking guests are AFCA's Honorary President, Maj. Gen. Anthony C. McAuliffe, Chief of the Chemical Corps; Rear Admiral John A. Snackenberg, Deputy Chief, Bureau of Ordnance, USN; and Maj. Gen. Richard C. Coupland, Director of Armament, USAF. All will have a special message to Annual Meeting attendants.

This year's meeting featuring a Navy "twang" will afford AFCA members the opportunity to gather first hand the operations of a sister service and at the same time witness demonstrations and entertainment as supplied by personnel of Norfolk Naval Base. Present planning includes an inspection visit to the battleship Missouri, providing the ship is "present and accounted for" at Norfolk.

This year's meeting will afford AFCA fishermen the chance of a lifetime to participate in deep-sea "hunting" as the Association's advance party reports the fish are running, tackle is available and boats plentiful. This, all in addition to reasonable off-season rates for boat hire.

Another feature of the three-day meeting will be a Chemical Corps exhibit depicting the functions of the Corps. This will be the first presentation of the exhibit off a military reservation and the display is reputed to be the Corps' finest in history.

AFCA's '50 meeting is being planned to combine fun with business; education with defense. It's definitely headed for the classification of a "best yet" affair. For the official "AFCA Travel Digest" see page 40. Train and rail schedules are presented for the information of all.

CIVIL DEFENSE PLANNING *A Progress Report*

By
Lt. Col. Barnet W. Beers, GSC

WITH THE NATION'S STATES AND MUNICIPALITIES CLAMORING FOR INFORMATION PERTAINING TO "WHAT'S THE STATUS OF OUR CIVIL DEFENSE PLANNING," THE JOURNAL PRESENTS AN EXCLUSIVE ARTICLE GIVING ANSWERS TO THE QUESTIONS.

ABOUT THE AUTHOR

Colonel Beers, who now serves as Assistant for Civil Defense Liaison in the Office of the Secretary of Defense, commanded the Civil Defense Team of the U.S.S.B.S. which investigated civil defense in Germany, Great Britain and Japan in 1944-'45. The next year he became Civil Defense Officer, Army General Staff, and Recorder of the War Department Civil Defense Board commonly referred to as the "Bull Board." In March, 1948 he was assigned as Executive to Russell J. Hopley in the Office of Civil Defense Planning where he served until August, 1949 at which time he assumed his present responsibilities.

In recent months there has been considerable press and radio attention to the problems of civil defense, to the extent that the public is beginning to understand the problems involved. However, there still is an inclination to apply the term "civil defense" to a variety of activities ranging from anti-atomic defense to proposals for the formation of armed vigilantes for internal security purposes.

Through a process of world-wide war experience and world-wide post-war planning, "civil defense" has come into international acceptance as a term covering a broad field of measures for the protection and welfare of urban communities against enemy attack that succeeds in penetrating the preventive functions of military defense and internal security. Civil defense includes civilian participation in military passive operations short of bearing arms. For use within the Department of Defense Secretary Louis Johnson, in a directive, dated 1 August 1949, defined the term "civil defense" to mean: ". . . all those activities and measures which are designed either (1) to minimize the effects which might otherwise be caused by, (2) to deal with the immediate emergency conditions created by, or (3) to repair any vital damage resulting from, an enemy attack which is successful in reaching a target within the United States, its territories, or possessions and which affects the civilian population. The principal activities in this field are (1) protection (such as shelters, fire services, sanitation, panic prevention and control, non-military evacuations, dissemination of warnings, and the like); (2) relief (such as rescue, emergency feeding and housing, emergency medical care and the like); and (3) rehabilitation (such as restoration of essential services, utilities, communications, housing, and the like)."

When the Office of Civilian Defense, which operated during World War II, was discontinued in June 1945, the War Department considered that planning for civil defense should be progressively maintained. It was therefore decided that the War Department should prepare a study looking to the future status of this highly important part of our overall defense. A board was appointed, headed by Lieutenant General Harold R. Bull. This board, after three months of exhaustive study, produced its report. The important conclusions of this board can be generally summarized as follows:

(a) Civil defense is a primary responsibility of civil government with principal preparations for operations at the local level; a recognition of state government responsibility for supervision of such activities within the state and with appropriate federal government coordination, assistance and support.

(b) Civil defense is an essential part of national defense; that the Armed Forces' primary mission of defeating an enemy should not be jeopardized by unnecessary diversion from this mission; but they should be responsible for technical advice and guidance in the fields in which they have special capabilities or knowledge and for rendering aid to civil authorities as prescribed by law and within limits that would not jeopardize that primary mission.

The "Bull Board" recommended: (a) a national policy group (such as the proposed National Security Resources Board); (b) a single permanent civil defense agency separate from the Armed Forces and, under a civilian director, to plan, organize, operate and in war-time to direct civil defense activities.

The Hopley Report

Acting upon these recommendations, the Secretary of Defense in March 1948 established the Office of Civil Defense Planning and Mr. Russell J. Hopley, a business executive, was drafted to direct the newly formed office. This group, which was composed of some 43 experts in their fields, together with some 200 consultant members, selected because of their special ability in their respective fields, spent some eight months working on this report. As a result, the report "Civil Defense for National Security" was submitted to the Secretary of Defense on November 14, 1948. This report was given country-wide distribution. It was generally accepted as the last word on civil defense planning and although today this report has not been either officially accepted or rejected, it forms the basis for civil defense planning at federal, state, and local governmental levels. It has been acclaimed by most of the foreign nations that have proceeded in civil defense planning, several of them virtually adopting the plan in its entirety. The plan expands on detailed functions and suggests federal, state, and local organization to carry them out in time of emergency. Prepared principally by representative civilians, the "Hopley Report" proposals are not at variance with the principles developed by the military "Bull Board" a year earlier.

On March 3, 1949, the President directed the National Security Re-

sources Board to assume leadership in planning for civil defense. Since that time considerable progress has been made.

After preliminary study and review of planning that had already taken place, the Board proposed a division of planning responsibility along lines that would utilize the experience and functional responsibility of existing agencies. Those activities generally classed as measures to meet war-time disasters were assigned for planning purposes to the newly formed General Services Administration with instruction to coordinate the planning with other appropriate agencies of government. Through this means, scores of individual planning projects have been initiated in other agencies such as numerous studies on health and welfare problems conducted by the United States Public Health Service and assisted by the Department of Defense. Interdepartmental committees have been formed to plan civilian measures in the fields of radiological, chemical, and biological warfare defenses. Technical guidance for civil defense planners has been developed by the Department of Defense and Atomic Energy Commission for issuance by the National Security Resources Board. Examples of these are: "Medical Aspects of Atomic Weapons" and "Damage From Atomic Explosion and Design of Protective Structures;" and many others of a similar nature covering other elements of defense are under preparation.

A series of letters have been sent to the Governors of the states by the Chairman of the National Security Resources Board, urging initiative on their part in approaching the civil defense problem and providing for the channeling through them to the organized communities further information as it is developed.

The report of the Office of Civil Defense Planning, entitled "Civil Defense for National Security" and commonly known as the Hopley Report, was referred to in one of these early letters as "a useful guide" to civil defense planners. The "Hopley Report" was officially distributed on 14 November 1948 to all Governors in sufficient quantities for a redistribution to municipalities within each state, and as a result, state and local planning in this field was considerably stimulated. Many of the states have passed new civil defense legislation paving the way for active planning and organization within the states, and most of the Governors have appointed a director of civil defense.

Civilian-Military Team

The National Security Resources Board has recognized the necessity for the development of a "civilian-military team" in many activities related to military defense. Many activities necessary in effective air defense and ground defense of the continental United States will require augmentation by civilian auxiliaries. Such activities are exemplified by the aircraft observer system to augment the radar screen established by the United States Air Force. Therefore, a program identified as "Civilian Participation in Active Defense" has been assigned to the Department of Defense. This program includes all activities controlled and operated by the military but which involves participation by civilians normally on a volunteer basis. In addition to the aircraft observer system, such activities might include auxiliary anti-aircraft, auxiliary patrols for military purposes, including some activities of the civil air patrol, beach patrols, "auxiliary power squadrons" in conjunction with coast guard activities. In these activities the manpower considerations are coordinated with National Security Resources Board; civil defense agencies at the state and local levels are required to assist in the recruiting and administrative end; but the planning and the operational control is accomplished entirely by appropriate military departments.

"Civil air raid warning" is to be planned by the military, integrated with air defense activities but actually implemented by civil (civil defense) authorities. Control of the warnings and regulations for conduct under various degrees of warning is to be prepared by the Department of Defense.

"Passive defense measures" required by military necessity, such as blackouts, dimouts, camouflage, electronic emissions control, and the like, are to be planned by the Department of Defense, including drafts of appropriate regulations; to be implemented and enforced by civil authorities.

"Protective construction" is generally the responsibility of the civil authorities, particularly as they pertain to shelter protection for the public. The military has the responsibility for leadership in protective construction as it applies to industrial protection for facilities essential to the war effort; and for technical advice and participation in the development of other shelter techniques and policies. Leadership and initiative in planning for protection of the general public presently remains with the agency of responsibility—National Security Resources Board.

It is a civil agency responsibility to plan for "unexploded bomb reconnaissance" (locating and identifying unexploded missiles; evacuating and isolating dangerous areas for civilian protection). It is a military responsibility to (a) neutralize or dispose of such unexploded missiles and to lend technical assistance and advice in planning the reconnaissance.

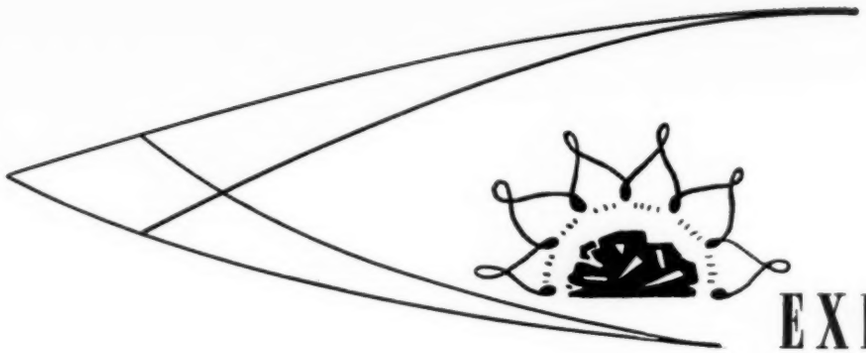
Support of Civil Defense

The problem of physical support of civil defense operations by military units requires considerable further consideration. The traditional dependence of civil authorities on the military in times of great disaster or other emergency creates a dangerous potentiality for diversion of the military forces from the primary mission of fighting a war. Under the existing constitutional and legal provisions for supplying military assistance to civil power, the three departments of the armed forces are prepared to render assistance to stricken communities to the greatest extent possible "within the means available and without jeopardy to their primary mission." Aside from the humanitarian reasons involved, the deep concern of the Department of Defense in problems of civil defense stems from this problem. It is considered highly essential to develop the highest possible civilian capabilities in the field of organized self-protection without reliance upon military assistance. As a final echelon of support, the military forces will render all feasible aid in isolated incidents.

The first actual implementation of a major activity under the current civil defense plan is the Aircraft Observer Corps.

Surveillance of our air frontiers in order to detect unidentified aircraft is essential to an adequate system of air defense. For this purpose Congress has recently appropriated specific funds for the establishment of a radar screen. Despite the many developments made in the field of electronics there are still technical limitations in the capabilities of radar detectors. These, and other limitations imposed by considerations of topography and economy, make it necessary to augment the radar screen by observers located throughout the surveillance area and by filter centers to screen, evaluate and facilitate the flow of useful information from the observer network to the air defense commanders. The value of an observer system is two-fold: first, it increases the capability of the air de-

(Continued on page 39)



EXPERIMENTS IN THE UNDERGROUND GASIFICATION OF COAL

SUCCESSFUL APPLICATION OF PROCESSES FOR GASIFYING COAL IN PLACE WILL MAKE AVAILABLE A SOURCE OF ENERGY FOR ELECTRIC POWER GENERATION AND GASEOUS PRODUCTS SUITABLE AS THE RAW MATERIALS FOR SYNTHETIC LIQUID FUELS MANUFACTURE.

By Milton H. Fies and James L. Elder*

The Bureau of Mines, U. S. Department of the Interior, and the Alabama Power Co. are interested in the underground gasification of coal from the standpoints of power generation, synthetic liquid fuels manufacture, and conservation of natural resources. In view of these mutual interests, the two organizations are conducting a series of experiments designed to develop the possibilities of this method of coal utilization.

Successful application of processes for gasifying coal in place will make available a source of energy for electric power generation and gaseous products suitable as the raw materials for synthetic liquid fuels manufacture. It offers a method of utilizing coal veins now difficult or uneconomic to mine, and it may be possible by proper application to recover the residual energy remaining underground in regions where pillars and blocks of coal remain unmined in abandoned coal operations.

Synthetic liquid fuels can be made from three major raw materials—coal, oil shale and natural gas. Of the three, coal is by far the largest potential source. Excluding atomic energy, coal is estimated to comprise more than 95 percent of our mineral fuel-energy reserves.

Two basic processes have been developed for converting coal into oil: (1) The direct-hydrogenation or Bergius process; and (2) the gas-synthesis or Fischer-Tropsch process. Both require the production of a gas as a preliminary—and costly—step.

In the first process, a large volume of hydrogen is required for catalytic addition to the coal under high pressure to produce liquid fuels directly. Hydrogen now constitutes 50 percent of the total cost of the liquid products.

In the second process, synthesis gas—a mixture of carbon monoxide and hydrogen obtained by gasification of carbonaceous materials—is required for catalytic conversion into liquid fuels. The production of synthesis gas now comprises 60 to 70 percent of the total cost of the products.

It is readily apparent that low-cost production of the required hydrogen and synthesis gas is the key to the entire problem of competitive liquid fuels from coal. Pure hydrogen can be obtained from synthesis gas by reacting the carbon monoxide with steam and removing the carbon dioxide formed. Therefore, development of an economical method for producing synthesis gas would aid immeasurably in solving the problem.

At this time, four major processes are in use for manufacturing gas. These are: Producer-gas process; cyclic water-gas process; continuous water-gas processes; and carbonization of coal.

As now applied, all these gas-making processes have entailed the use of mined coal and costly equipment, with the result that the product has been a relatively high cost gas.

The Bureau of Mines and the Alabama Power Co. have jointly conducted and completed one field-scale experiment in the underground gasification of coal and at present are cooperating in a second field-scale experiment. The Bureau of Mines has in addition carried out laboratory-scale investigations relating to the same subject.

First Field-Scale Experiment at Gorgas, Ala.

Late in 1946, the Bureau of Mines and the Alabama Power Co. began constructing the first field-scale experiment at Gorgas, Ala.

Briefly, two 150-foot parallel entries were driven in the Pratt coal bed underlying a small peninsular hill with a surface area of approximately 3½ acres (Fig. 1). This seam was connected with a main body of 19,000 acres of coal in which a large mine was in operation but was isolated by an open-cut through the north end of the peninsula. The parallel entries were connected at their extremity by a crosscut, forming a U-shaped path around a pillar of coal averaging 150 feet in length and 40 feet in width. The portals were sealed, and pipes for admitting and taking off air or gas were placed in each seal. Air could be blown through the system and the flow reversed as desired, the gas always being removed from the portal opposite the air entry. The installation was completed in January 1947, and immediately the project was fired and experimentation begun. The coal was ignited by dropping thermite bombs through a vertical test hole into a pile of loose coal that had been piled in the cross-

*Mr. Fies is Consulting Coal Mining Engineer, Office of Synthetic Liquid Fuels, Bureau of Mines, U. S. Department of Interior; Manager Coal Operations, Alabama Power Co.; Consulting Mining Engineer, The Southern Co., Birmingham, Ala. Mr. Elder is Supervising Engineer, Gorgas Underground Gasification Project, Office of Synthetic Liquid Fuels, Bureau of Mines, U. S. Department of Interior, Gorgas, Ala.

cut, forming the base of the U-shaped passage. Details and results of this first experiment are to be found in several papers.[4, 5, 6].

This experiment was continued for 50 days. At times tests were made using a blast medium of oxygen-enriched air, oxygen-steam, or steam in a cyclic operation, as in the production of water gas. The greater part of the first Gorgas experiment, however, was made with a simple air blast.

For the first 8 days the operating conditions were unsteady; the back pressure increased; and many delays and shut-downs were necessary. The average heating value of the gas produced per run varied from 21 to 48 B.t.u. per cubic foot, with an average value of 36 B.t.u. per cubic foot. The average gas composition was:

	Percent by volume
CO_2	14.8
O_2	1.3
Illuminants	.1
H_2	3.9
CO	1.9
CH_4	1.5
N_2	76.5

During the last 42 days of the experiment the back pressure remained constant, and operating conditions were much more stable. During this period, the average heating value of the gas produced per run ranged from 28 to 68 B.t.u. per cubic foot, with an average value of 47 B.t.u. per cubic foot. The average gas production was 108 cubic feet of gas per pound of coal burned and ranged from 140 to 92 cubic feet. The cold-gas efficiency ranged from 28.0 to 50.9 percent, with an average value of 40.9 percent. The average gas composition during this period was:

	Percent by volume
CO_2	15.2
O_2	1.0
Illuminants	.2
H_2	5.5
CO	3.1
CH_4	1.5
N_2	73.5

Near the end of the experiment during a 15.5-hour east-west air-blast run, the gas production was 97.6 cubic feet per pound of coal burned, the efficiency was 50.9 percent, and the average heating value of the gas produced was 65 B.t.u. per cubic foot. During the following 10.25-hour west-east air-blast run, the gas production was 91.8 cubic feet per pound of coal burned, the efficiency was 50.7 percent, and the average heating value of the gas produced was 68 B.t.u. per cubic foot. These air-blast runs gave the best results of any that were made during the course of the experiment, but it is believed that the quality of gas and the efficiency are not as high as can be achieved. Individual gas analyses of samples of effluent gas showed that the heating value at times reached 76 B.t.u. per cubic foot, and samples taken at specific points within the mine gave calorific values as high as 128 B.t.u. per cubic foot.

During one week, gas was taken from several test holes and burned under a small boiler supplying steam for the experiment. A total of 450,000 cubic feet of gas, with an average heating value of 70 B.t.u. per cubic foot, was burned during this period, and the average composition of the gas was:

	Percent by volume
CO_2	11.7
O_2	.4
Illuminants	.2
H_2	7.0
CO	9.1
CH_4	1.4
N_2	70.2

This gas taken from the test holes was considerably lower in carbon dioxide and much higher in carbon monoxide and hydrogen than the product gas sampled at the outlets. In addition, the heating value often reached 90 B.t.u. per cubic foot, and the maximum determined value was 108 B.t.u.

From this preliminary experiment, in which approximately 400 tons of coal was coked or burned, these conclusions were drawn:

1. Combustion of coal in a solid stratum underground can be maintained.

2. Coal in place in this instance was gasified completely. Examination of the residue showed that only ash and clinker remained in the combustion zone. No islands of unreacted coal or coke were found.

3. Coking preceded actual combustion.

4. The high temperature developed by the gasification brought about changes in the overlying strata that appeared favorable to the process. Roof rock became plastic, expanded, and settled on the mine floor directly behind the reacting coke face. Settlement of the roof rock forced the air and gas to pass through the narrow openings along the coke-rock interface. The formation of these narrow openings increased the pressure drop through the system but did maintain contact between the blast medium and hot carbonaceous surfaces.

5. Volume and velocity of air circulated were not sufficient to give temperatures necessary for optimum results.

6. A product gas of varying quality was produced by the several methods employed. It appeared that a power gas could be produced by the use of air, air-steam, or oxygen-enriched air and that a synthesis gas apparently could be made by using an oxygen-steam blast, or through a cyclic operation employing a steam run.

Laboratory Experimentation

A horizontal, rectangular, laboratory-scale retort was built at the Bureau of Mines station at Morgantown, W. Va., to investigate some of the problems and proposed methods of underground gasification of coal at a fraction of the time, labor, and cost required for field-scale operations.[7, 8] The retort (Fig. 2) was contained in a steel jacket, open at the top, constructed of standard refractory materials and insulated with diatomaceous earth. Inlet and exhaust openings to the retort were provided with regenerators and suitable equipment for handling air and product gas. The retort was altered repeatedly in size and construction as experimentation progressed, remaining, however, essentially horizontal and rectangular.

During the first test runs, a gas comparable to that in the first field-scale experiment at Gorgas was produced—that is, having a heating value of approximately 50 B.t.u. per cubic foot. A marked improvement in gas quality was noted as experimentation continued. Table 1 gives the results of four of the last runs. The calorific value ranges from 92.4 to 111.6 B.t.u. per cubic foot.

[4] Dowd, James J., Elder, James L., Capp, J. P., and Cohen, Paul, Experiment in Underground Gasification of Coal at Gorgas, Ala.: Bureau of Mines Rept. of Investigations 4164, 1947, 62 pp.

[5] Fies, Milton H., and Schroeder, W. C., Underground Gasification, An Account of Experiments on Coal, Conducted at Gorgas, Ala.: Mech. Engineering, February 1948, pp. 127-135.

[6] Fies, Milton H., The Gorgas, Ala., Experiment in Underground Gasification of Coal: Trans. Canadian Inst. Min. and Met., vol 51, 1948, pp. 234-247.

[7] Synthetic Liquid Field 1948 Annual Report of the Secretary of the Interior: Bureau of Mines Report of Investigations 4456, 1949, pp. 41-47.

[8] Fies, Milton H., and Elder, James L., Laboratory and Field-Scale Experimentation on the Underground Gasification of Coal, presented at United Nations Scientific Conference on the Conservation and Utilization of Resources, Lake Success, N. Y., Aug. 22, 1949.

TABLE 1.—*Results of Laboratory Experiments*

Experiment	7	9	10	11
Wt. of charge ..... lb.	5,180	8,738	8,185	8,030
Wt. of residue ..... do.	1,453	4,920	4,717	2,002
Percent consumed	72	44	43	75
Max. air flow ..... cu. ft. per hr.	2,350	3,642	4,600	2,940
Analysis of charge:				
Hydrogen ..... percent	4.6	4.2	4.2	4.5
Carbon ..... do.	75.9	75.6	78.2	76.6
Nitrogen ..... do.	1.2	1.3	1.3	1.4
Oxygen ..... do.	6.1	5.6	4.7	6.2
Sulfur ..... do.	.9	1.3	.9	.9
Ash ..... do.	11.3	12.0	10.7	10.4
Heating value ..... B.t.u. per lb.	13,220	13,010	13,390	13,250
Length of run ..... hr.	109.25	83.5	46.3	124.5
Gasification period ..... do.	31.5	52.0	20.3	22.5
Av. gas analysis:				
CO_2 ..... percent	8.7	10.2	7.7	7.7
Ill. ..... do.	.2	.6	.5	.3
O_2 ..... do.	.2	.2	.5	.4
CO ..... do.	19.9	12.1	14.7	20.9
H_2 ..... do.	4.3	9.5	10.7	4.5
CH_4 ..... do.	1.9	2.4	2.0	2.3
N_2 ..... do.	65.7	65.0	63.9	63.9
Heating value ..... B.t.u. per cu. ft.	92.4	106.1	111.6	111.4
Cold-gas efficiency ..... percent	55.6	75.0	80.9	64.5

During some of the test runs, the relationship between oxygen, carbon dioxide, and carbon monoxide was determined. This was shown by analysis of gas samples taken after the air-gas had traveled 5, 20, 50, 70 and 95 percent of the length of the channel. These analyses clearly show a decrease in oxygen and an increase in carbon dioxide, then a decrease in carbon dioxide and an increase in carbon monoxide as the percentage of travel through the channel increases. The 5-percent point was characterized by high oxygen, the 20-percent by high carbon dioxide, and the 50-, 70-, and 95-percent points by increasing percentages of carbon monoxide, with a maximum percentage at the 95-percent point and in the product gas.

The laboratory tests indicated that it should be possible to use a simple air blast and produce a gas having a heating value of 100 or more B.t.u. per cubic foot by underground gasification, provided similar conditions could be established and maintained underground.

Second Field-Scale Experiment at Gorgas, Ala.

The results of the first Gorgas experiment and the laboratory work that followed led to construction of the present larger-scale underground gasification project at Gorgas, Ala.[9, 10] This experiment is being conducted in the Pratt coal bed in an area isolated from the main body of coal by nature and consisting of approximately 100 acres. The coal seam is 42 inches thick and relatively level; it lies under an average overburden of 150 feet.

[9] Literature cited [7, 8]

[10] Fies, Milton H., The Second Experiment in the Underground Gasification of Coal at Gorgas, Ala., and Its Progress, presented before the Analysts Society of New York, New York, N. Y., November 30, 1949.

The experimental unit consists of a straight-line passage in the coal, with surface connections at one end through an outcrop seal, and at various points along its length through vertical boreholes. The installations for this experiment are shown in the schematic diagram (fig. 3). The underground passage is divided into five sections, the one extending from bore hole V to the entry seal being 200 feet in length and the other four sections 300 feet in length. Each section may be used separately as a unit, or several sections may be combined to form one large unit. The passage in the coal bed consists of two parallel entries 10 feet wide, separated by a solid pillar of coal 10 feet thick except for the inby section between bore holes I and II, which is a single 10-foot-wide entry. The large bore holes are drilled into crosscuts connecting the entries.

A wide choice of operating methods may be employed during the experiment. Initially it was planned to use a simple, continuous, unidirectional air blast, although provision was made for reversal of the air blast. The use of steam also is possible, either intermittently, as in a cyclic water-gas operation, or continuously with air. Oxygen has been considered for use in underground gasification, but its cost, in large quantities, is prohibitive at present, and for this reason much of the experimental work will be done with air.

The objectives of this second underground gasification experiment are:

1. To determine the quantity of coal that can be gasified from a given initial combustion zone and the shape and extent of the burned-out areas formed during this gasification.

2. To test the design and installation of types of fixed product-gas outlets, including the seals required.

3. To determine the operational characteristics of the experimental installation under such variation of conditions as the nature of the installation and the progress of the work may indicate to be desirable—for example, the length of passage required, the optimum rate of flow, and the pressure drop.

4. To determine the quality and quantity of the product gas generated and the secondary byproducts evolved under the experimental conditions.

5. To obtain all possible information regarding the action of heat on the overlying strata.

6. To develop, without interfering with the foregoing objectives, such fundamental technical and economic in-

Fig. 4—Two-cylinder reciprocating compressor, 7200 c.f.m., discharge pressure 30 p.s.i.g.

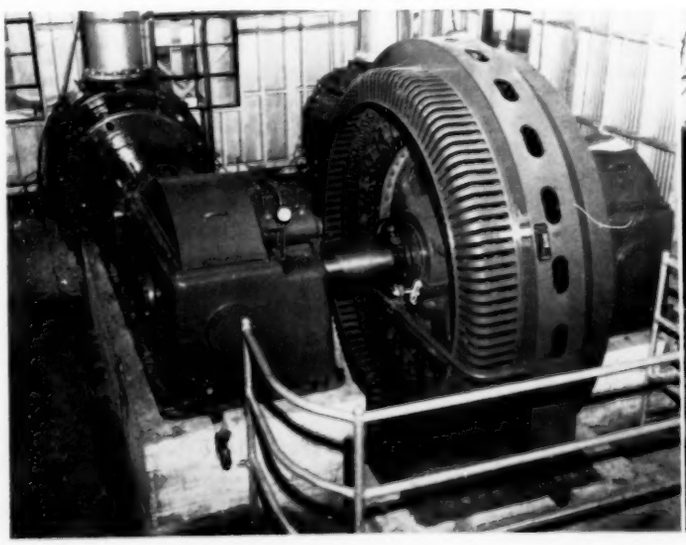


Fig. 5—Twenty-inch air manifold

formation as is likely to be helpful in selecting plant sites, plant installations, and operating processes. Testing of refractory linings and installations designed for handling hot gases is included.

The construction of the underground gasification unit at Gorgas, designed to operate 1 year or longer, required equipment and construction work on a magnitude comparable to that of a small industrial plant. A two-cylinder reciprocating compressor (fig. 4) designed to deliver 7,200 cubic feet of air per minute at 30 pounds per square inch gage has been installed. This source of air is connected to the five bore holes by means of a valved 20-inch-diameter manifold (fig. 5).

To develop the area assigned to the experiment, entries were driven into the coal bed, and conveyors were used to load out and transport the coal to the surface.

Two 18-inch bore holes, I and V, and three 28-inch bore holes, II, III, and IV, were drilled from the surface to the entry as shown in fig. 3 by means of a churn drill. The strata through which each bore hole passes were pressure-grouted by means of four 6-inch churn drill holes spaced 4 feet from the center point of the large hole. At each location the first two holes took appreciable quantities of cement grout—and the last two refused to take grout, indicating the underground crevices intersected by the holes were securely stopped.

The five large bore holes were sealed at the surface by lengths of water-jacketed pipe set in concrete. These seals extend approximately 25 feet below the surface and were seated in hard rock.

The two 18-inch-diameter bore holes were unlined below the seal. It is possible that the natural strata will crumble and slag at high temperature, blocking the bore hole; however, it seemed advisable to test this type of construction. A refractory lining has been installed in the three 28-inch holes. A 20-inch-diameter pipe casing was set in each hole, and a refractory concrete mix was poured into the 4-inch annulus.

In addition to the large bore holes, a number of test holes were drilled to measure the temperature rise in the coal bed. These were placed in a pattern so arranged that the progress of the combustion zone could be traced.

The entry seal consists of a wall extending across and 25 feet beyond the ribs of the entries. This wall extends 6 feet into the roof rock and 2 feet into the bottom. It was constructed of three courses of fire brick, backed and sealed with concrete and cement grout. Outlet pipes, 24 inches in diameter and fitted with blow-out disks, have been set in the wall. The design and testing of an entry seal are requisites in underground-gasification experimentation.

Combustion was started near the bottom of bore hole I in the entry at the end farthermost from the outcrop. Air was supplied at bore hole I, and products of combustion was taken off 300 feet away at bore hole II. A low rate of air blast was used initially and gradually increased as combustion was established. For a few days after ignition the gases evolved showed decreasing percentages of oxygen and increasing percentages of carbon dioxide. After 10 days operation the high-temperature zone underground moved downstream and was near the base of bore hole II, and the oxygen content of the effluent gases was increasing. The direction of flow was reversed in an effort to distribute combustion over the entire 300 foot passage, and since this first 10-day period of unidirec-

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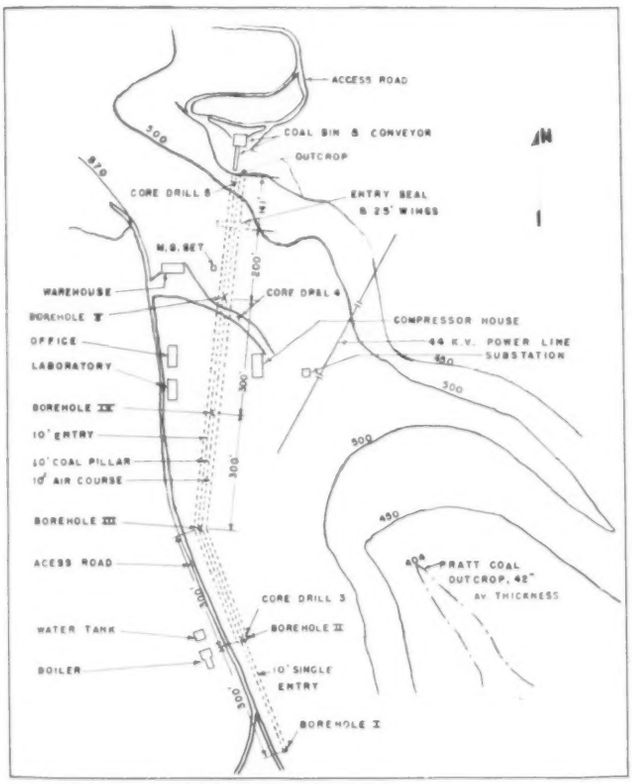

Fig. 1—Plan of gasification mine

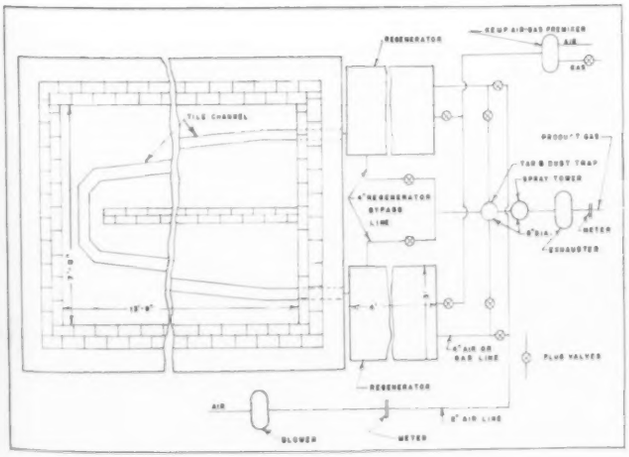

Fig. 2—Plan of laboratory-model underground gasification unit

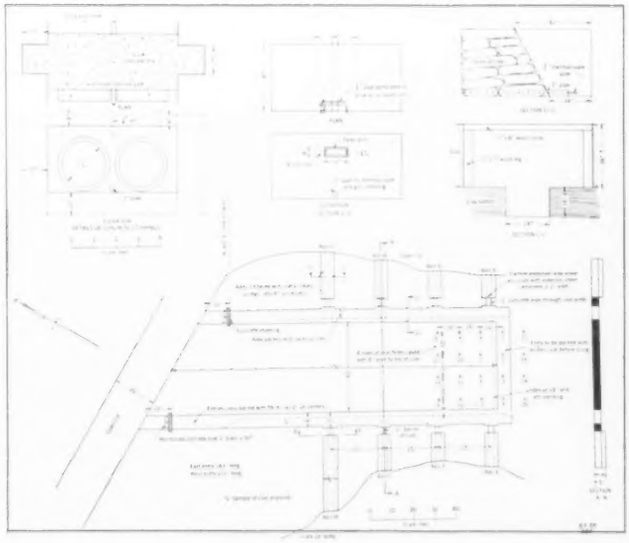

Fig. 3—Plan layout; plan of underground gasification project

AIRPLANE SPRAY APPARATUS

THE EVOLUTION OF THE RAM GRAVITY-TYPE SMOKE TANK

A REVIEW OF THE EVOLUTION OF ONE PIECE OF EQUIPMENT—DEVELOPED AND HELD IN RESERVE BY THE CHEMICAL CORPS DURING WORLD WAR II—FOR THE DISPERSION OF TOXIC AGENTS, SMOKES AND INSECTICIDES FROM THE AIR.

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The Chemical Corps of the Army is somewhat like a fire department in civil life. The principal job of such a department is to extinguish fires. If necessary, it may even use fire to fight fire. So it is with the Chemical Corps, even more than with other branches of the Army. One mission of the Chemical Corps is to prepare our forces for toxic chemical warfare (poison gas and related substances). The experiences of World War II demonstrated that it was the thoroughness of these preparations, more than any other factor, that prevented our enemies from employing this type of warfare.

This paper is a brief review of the evolution of one piece of equipment developed and held in reserve by the "fire department," a type of munition for the dispersion of toxic agents, smokes, and insecticides from the air. Various types of airplane spray apparatus have been developed. We will consider here the evolution of the gravity-type airplane spray tank which, in its simplest form, consists of a streamlined container, an air inlet system to direct air into and produce a ram pressure within the tank, a discharge system to direct the contents of the tank away from the airplane, necessary closure devices, and a method of attaching the apparatus to the airplane.

*The use of the expression "gravity-type" originated with the early apparatus, which depended entirely upon gravity to discharge the contents of the tank. Later, ram pressures were used to improve the performance of the tank, but the expression "gravity-type" was retained to distinguish this type of tank from those using tank pressures in excess of 25 lbs. per square inch to effect discharge of the contents.

Methods of Smoke Generation

Several different methods of generating smoke from aircraft for use in skywriting, signalling, or the laying of smoke screens are available. These methods can be classified as follows:

1. Use of burning-type smoke-producing mixtures.
2. Injection of oil or other smoke-producing materials into the exhaust of the airplane engines, or the use of some other heat source.
3. The release of hygroscopic smoke-forming materials from pressurized or gravity flow-type containers.

This discussion will be limited to a presentation of the evolution of the gravity-type airplane smoke tank in this country.* Since such tanks can also be employed for the dispersion of other chemical agents, such expressions as smoke tank, spray tank, airplane chemical tank, etc., are used synonymously.

Early Apparatus—The Exhaust Method

As early as 1923, an apparatus to be used for the indirect control of gunfire was designed for generating smoke suitable for signal purposes from some of the seaplanes of that day. In this installation, FM (titanium tetrachloride) was introduced under pressure into the exhaust manifold of the engine, where it was volatilized by the hot exhaust gases and, when coming in contact with the moist air of the atmosphere, produced a dense white smoke. This apparatus was very crude, but worked satisfactorily and suggested an extension of the work to the

Fig. 1—THE B-1 SMOKE TANK TANK

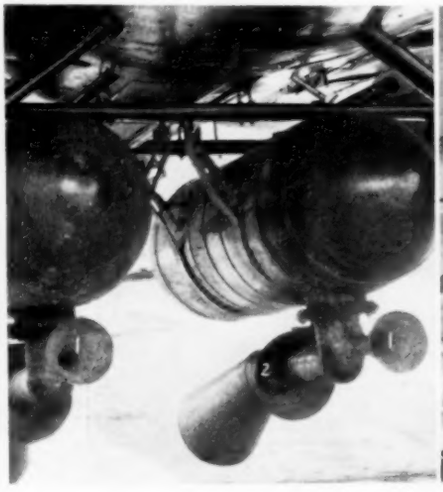


Fig. 2—THE E1R1 SMOKE APPARATUS
A temporary expedient pending development of improved apparatus

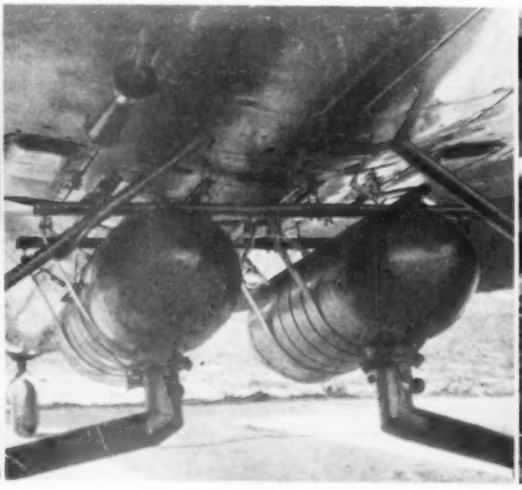


Fig. 3—THE E2 SMOKE TANK
A result of new emphasis . . .

generation of smoke for screening ships and other objects, using the same method on a large scale. FM was again used as a smoke-producing agent and was contained in a 15-gallon tank, under a pressure of 125 lbs. per square inch. Approximately 160 lbs. of FM was discharged through the four exhaust manifolds of the F-5 airplanes used in the tests, and a very effective smoke cloud was produced.

The Sprinkling Method

In the course of this experimentation an accident occurred, during which the FM was ejected directly into the air, without first passing through the hot exhaust manifold. The resultant smoke cloud appeared to have the same characteristics as the smoke clouds previously obtained. Advantage was taken of this new method of smoke generation in the development of new equipment. FM was ejected from a nozzle directly into the air to the rear, with a velocity approximately equal to the air speed of the airplane. This method of smoke dispersal was commonly known as the sprinkling method. The pressure required for delivering FM was obtained from an auxiliary cylinder of carbon dioxide. The apparatus installed in the early Martin bomber, which was the forerunner of a line of pressure-type spray tanks not discussed in this paper, consisted essentially of two tanks, connected on one hand with a cylinder of compressed carbon dioxide and, on the other hand, with a pipe leading to a nozzle near the tail of the airplane. The FM tanks, having a capacity of 35 gallons each, were standard 300-lb. phosgene drums, modified by the addition of a 1½-inch discharge opening on the lower side, and a ⅜-inch pressure line connection and a 1½-inch filling opening on the upper side. The tanks were suspended side by side in the bomb bay of the airplane, and were connected together by suitable piping to permit the discharge of FM from both tanks individually or simultaneously. Provision was also made for the discharge of the smoke agent into both exhaust manifolds as well as directly into the air. The tanks had a combined capacity of 900 to 1,000 lbs. of FM, which was discharged under carbon dioxide pressure obtained from a 20-lb. cylinder. The pressure used depended upon the nozzle design; the speed of the airplane, in the case of the sprinkling method; and, within limit, upon the density of the screen desired in the case of the exhaust method. It was found that approximately 800 to 1,000 lbs. of FM, discharged directly into the air, produced an effective smoke curtain 600 feet high, and approximately one mile long. When the exhaust method was employed, 80 to 100 lbs. of FM was required to produce an effective screen 100 feet high and the same length. The particle size of the smoke, when the exhaust method is used, is considerably smaller than that obtained using the sprinkling method and, therefore, the effective height of smoke curtain would be expected to be very much less.

The Atomization Method

These early attempts to disseminate smoke and other chemical agents directly into the air from airplanes in flight necessitated the use of auxiliary pressure cylinders and tanks of such weight and strength as to withstand high pressures. Upon the advent of airplanes of higher speeds and lower load-carrying capacities, the sprinkling method was superseded by the atomization method, in which smoke-producing material was discharged by gravity below the slip stream of the airplane, where it was broken up and largely atomized by the shearing effect of the air. While the fundamental principle of the atomization method has changed little since its inception, the mechanical details of the equipment have changed to keep pace with changes in the design and types of aircraft. These changes in details of equipment involved sizes and shapes of tanks, manner of control, rates of discharge, discharge nozzle design, manner of suspension, and the location of the installation on the airplane.

The First Fuselage Suspension

The first application of the fuselage suspension resulted in the design of a tank conforming in general to the auxiliary fuel tank for the Army P-1, P-1A, P-1B, and corresponding Navy pursuit-type airplanes.

This tank had a capacity of approximately 25 gallons of chemical agent which could be discharged in approximately 23 seconds, giving an effective path of agent of approximately one mile in length. A hinged-type discharge line was used with the tank to permit the release of liquid sufficiently far below the airplane to prevent contamination of the fuselage and tail surfaces during discharge. In order to provide ground clearance during take-off and landing, the discharge line was elevated to a horizontal position directly below the fuselage. To produce smoke, the pilot released the tension on a control cable, allowing air pressure to force the discharge line into a vertical position. On coming into this position, the discharge valve pressed against a valve stem and opened the poppet discharge valve and the air inlet valve, permitting the liquid to discharge. Upon pulling up the discharge line, the discharge valve and the air inlet valve were closed. The

Fig. 4—E6R7 SMOKE TANK
A change from manual to spring operation

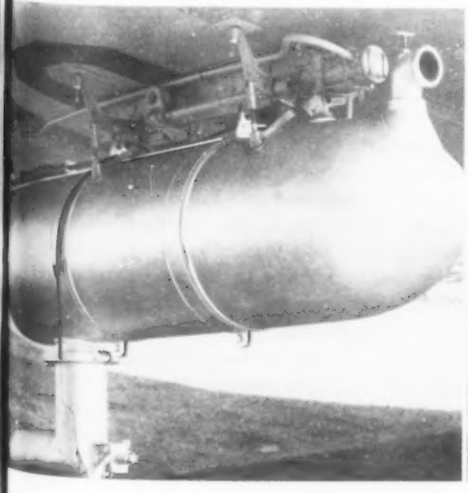


Fig. 5—AIR FORCE "KNIFE CUTTER" TANK
Capacity, 20 gallons — Discharge time, 6.5 seconds

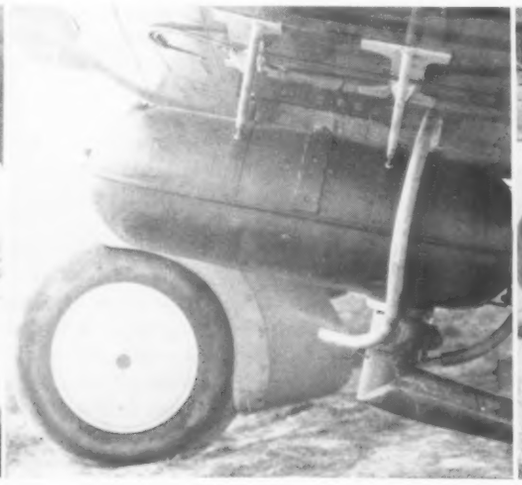


Fig. 6—INTERMITTENT DISCHARGE TANK
Developed in line with economy measures . . .

Fig. 7—M33A1 TANKS INSTALLED ON F-38 FIGHTER PLANE
Incorporated a stronger and improved container

earlier tanks did not make use of the air scoop type of air inlet incorporated in this tank. Some tests were also conducted on a telescopic type of discharge line. The smoke as it passes the tail of the ship takes the form of a rapidly widening cone with a tendency to fall. For use on the A-3 attack airplane, the tank capacity was increased to permit the carrying of 30 gallons of FM and the controls were placed in the rear cockpit. An effective screen approximately 6,000 feet long with a maximum height of 100 feet was obtained, the 30 gallons of FM being discharged in 25 seconds. This apparatus weighed 125 lbs. empty, and 545 lbs. when filled with 30 gallons of FM.

Wing-Tank Installation on the Navy O-2-U Airplane

Because of the design characteristics of the Navy 0-2-U airplane, it was impossible to adapt for use on this airplane the fuselage smoke tank equipment developed for the A-3 airplane. The smoke apparatus designed for the Navy 0-2-U airplane in 1928 consisted of two cylindrical tanks with streamlined ends to reduce air resistance, suspended from wing bomb racks, short rigid discharge lines, and lever-actuated poppet-type valve and vent mechanism. These tanks could be jettisoned from the airplane. The manual controls were operated from the rear cockpit. The discharge lines were made sufficiently short and close coupled with the tank, not only to give adequate ground clearance but also to provide a minimum clearance of 16 inches to prevent interference from the arresting wires on the decks of aircraft carriers. A venturi-type discharge line was also tried on this tank in an effort to obtain improved performance. Two tanks with a net filling capacity of 15 gallons each constituted full equipment for a single airplane. Each tank had a discharge time of approximately 13 seconds, which gave an effective smoke screen of 3,400 feet in length when both tanks were operated together. The use of a two-tank system permitted both tanks to be operated individually or simultaneously; when operated simultaneously, a pattern of twice the density and half the length of the spray pattern from a single tank was obtained. These tanks were suspended well out on the under surface of the wing at a safe distance from the fuselage and landing wheels. Because of this condition, together with the fact that the tail assembly of the airplane was elevated to a considerable distance above the horizontal line to permit its use as a seaplane by the substitution of pontoons for the landing gear, no contamination of either the fuselage or the tail assembly resulted when the tanks were discharged. The weight of two empty tanks made of monel metal was 97 lbs. When filled with FM, the tanks weighed 517 lbs.

Effect of FS on Smoke Tank Design

With the advent of the use of FS (a highly corrosive smoke mixture composed of sulphur trioxide and chlorosulfonic acid), those previous types of smoke tanks which contaminated parts of the airplane during the release of the chemical agent were found unsuitable. The hinged discharge line for the smoke apparatus used on the A-3 airplane had proved satisfactory with FM, but the small amount of contamination of the airplane which occurred when the hinged portion of the discharge line was raised, preparatory to landing after discharge of the agents, made it unsafe for use with FS. The small amount of liquid pocketed in the recess of the hinged joint was deflected by the air against the bottom of the tank and fuselage, and some of the smoke frequently entered the cockpit. The discharge line finally adopted to remedy this condition consisted of an 11-foot section of metal tubing connected to the discharge mechanism by a short section of flexible metal hose, with provision for raising and lowering the free end of the rigid section. A supplementary closure on the discharge end of the line was developed to avoid contamination of the airplane by the material entrained in the discharge line. This device consisted of a swinging cap, hinged at the top and connected to a push rod through a lever in such a way that a forward motion of the rod opened the closure and a backward motion closed it.

The apparatus developed for use on the Navy 0-2-U airplane was proving so superior to the belly tank installation with the swinging discharge line of the A-3 airplane that it was decided to adapt the smoke apparatus previously designed for the Navy 0-2-U airplane to the Army A-3 attack airplane which, for the first time, was being equipped with wing bomb racks. The advantages of this installation were lighter weight, increased loading efficiency, ease of manufacture and installation, and simplicity of operation. The A-3 airplane differed from the 0-2-U airplane in that the bomb racks of the former were nearer to the fuselage and directly behind and in line with the landing wheels. The tail assembly was much lower than that of the 0-2-U airplane and on almost the same level as the discharge lines of the wing tanks when in horizontal flight. These conditions, together with the fact that the discharge lines on the 0-2-U tanks were of close-coupled construction, resulted in serious contamination to the wing surfaces, fuselage, and tail assembly of the airplane. In order to overcome these difficulties, the vertical member of the discharge line was lowered 9 inches and the horizontal member extended 15 inches farther to the rear. A self-closing drip cap was also incorporated in the outlet end of the discharge line to prevent the contamination of the airplane in the event it was desired not to jettison the tanks. In other respects such as shape, size, capacity, rate and time of discharge, and methods of attachment and control, these tanks were identical with those originally designed for the 0-2-U airplane. This smoke apparatus, developed for use on the A-3 airplane, was designated the E1 smoke tank.

The Army Air Forces subsequently modified this tank by the addition of a funnel to the air inlet of the vent line, a reduction in the size of the discharge outlet, and the addition of a venturi tube to the end of the discharge line in an effort to obtain increased atomization of the liquid and decreased contamination of the airplane when installed on the A-3, A-8, and A-12 airplanes. This apparatus was designated the B1 smoke tank, but did not prove any superior to the E1 apparatus; both tank installations, when installed on the A-12 airplane, resulting in contamination of the airplane when spray was released. In order to eliminate this contamination, the discharge lines were offset outward a distance of 28 inches from the longtitudinal axis of the tank, and backward a distance of 30 inches from the center of the valve opening. This modified installation, E1R1, was considered a temporary expedient pending the development of improved apparatus more in keeping with advanced airplane design. The B1 and E1R1 apparatus mounted on the A-12 airplane are shown in Figures 1 and 2, respectively.

Spray Tanks for Storage of Filling

The tanks so far described were designed for filling just prior to use. In 1932 emphasis was placed on the development of airplane smoke tanks capable of being filled at a depot, stored for an indefinite period of time and then shipped, when required, to the airport, where they could be quickly and safely prepared for use by the attachment of suitable discharge lines. The E2 smoke tank was the first tank developed as a result of this new emphasis (Figure 3). It was very similar to the E1 tank in shape, size, and over-all dimensions, being 55 inches long, 12 inches in diameter, and having a capacity of 19 gallons. The tank, reinforced by three 3/16-inch beads rolled in its circumference and by two internal baffles, was suspended from the carrying lugs on the A-3 bomb rack and was jettisonable. The discharge mechanism was a radical departure from the previous types. The release valve was of the dump type and consisted of a hinged closure plate assembly covering the end of the discharge and vent lines from the outside.The assembly comprised an outside plate, a gasket, an interior retainer plate, a hinged operating lever, a locking latch, a closing spring, and a tension-adjusting screw. The closing spring provided moderate pressure on the closure plate and gasket to prevent dripping of the liquid after discharge in cases where it was desired to retain the equipment for further use. Operation was by means of a control cable attached to the operating lever and extended through a flexible cable housing to the cockpit of the airplane. This apparatus functioned satisfactorily, although at times the discharge rate appeared nonuniform, in comparison with the discharge from previous apparatus. This can probably be attributed to the fact that the vent was in an area of negative pressure and that the type of vent (air inlet) used in previous installations made use of the dynamic air pressure to increase the pressure in the tank during discharge as well as to scavenge the tank of its liquid contents after the main discharge had taken place.

In an effort to simplify the discharge line still further, several new ideas were tested with unsatisfactory results. In one case, a simple tear-strip device was used instead of the hinged closure, and attempts made to peel off this soldered strip in a manner similar to the opening of a sardine can. When the soldered strip was held sufficiently tight to be safe, excessive force was required to remove it. In another case, the closure cap was attached by means of low-melting solder and designed to be released by the ignition of a pyrotechnic mixture contained in an annular space surrounding the end of the discharge line. Ignition of the pyrotechnic mixture was accomplished by the use of an electric squib, but static tests indicated this device to be unsatisfactory. The use of frangible closure plates was suggested at this time but, because of the apprehension of accidental breakage of glass and the lack of resistance of plastic materials to corrosive agents, the suggestion was not adopted. Both plastic and glass closure plates have since been employed successfully for sealing smoke tanks.

An effort was made to decrease the cost of production of the E2 smoke tank by making the container of lighter construction, without internal baffles and fitted with a detachable carrier which would permit the expenditure of the tank without sacrificing the carrying bracket. This basic design of detachable carrier was incorporated in the E4 smoke tank, which was carried on the A-12 airplane and was developed to provide a container that could be used for long-time storage of a chemical agent and also provide an inexpensive chemical-dispersing apparatus capable of being expended in whole or in part after use. The tank was a modified standard 15-gallon steel drum provided with two end openings and rolling hoops. The modification consisted of the addition of a side outlet of oval cross section and a metal collar with a bevelled flange attached, in a manner identical with the tank of airplane tank apparatus E2. A bevelled closure plate with a bolted-type split-ring clamp was provided to permit the tank being filled and sealed for storage. This closure plate was interchangeable with the flanged member of the discharge line, the split-ring clamp serving to attach the discharge mechanism at the time of final assembly. The discharge mechanism was substantially the same as the hinged and spring-operated closure used on the E2 tank. Two controls were provided with this apparatus, both of which were operated from the rear cockpit of the airplane. One control released the locking latch and opened the valve simultaneously. The second control operated the release latches of the carrier and permitted the tank to fall, leaving the carrier attached to the bomb rack.

Airplane smoke apparatus modeled after an early tank, built for the A-3 airplane except that the discharge line was twice the normal size, was constructed so that tests could be carried out to determine the effect of doubling the size of the discharge line on the size of the spray particles obtained. Since tests showed that there was no change in the particle size, smoke apparatus E5, modeled after the E4, but having a discharge line of three times

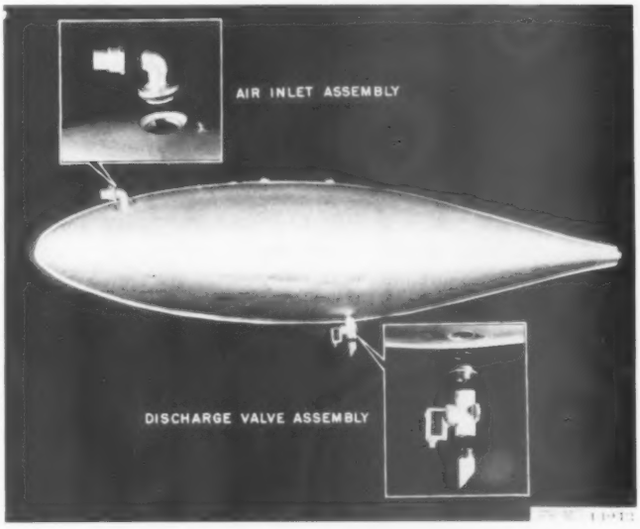
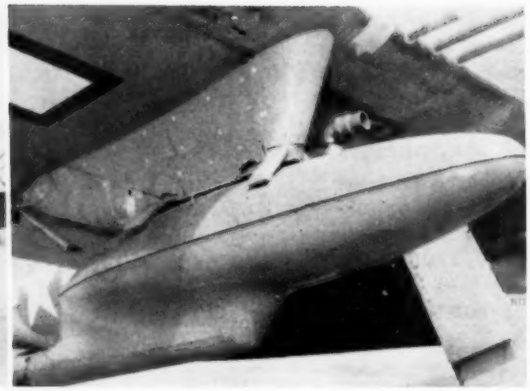


Fig. 8—THE E20 INSECTICIDE SPRAY TANK
A 165-gallon jettisonable fuel container



the normal capacity was developed. The same approximate dimensions with respect to height and length were retained but the outlet end of the line was finished in a square cutoff instead of the 45° angle and given an oval-shaped opening with a horizontal instead of a vertical major axis. The closing feature was similar in design but larger than that previously used and the vent mechanism was of the poppet type, installed in the forward end of the tank instead of within the discharge line as was done in the E4 apparatus. This vent mechanism was connected to the discharge valve closure by means of a push rod and opened and closed simultaneously with the operation of this member. Experiments at that time showed that the particle size of the discharged liquid was influenced very little by increasing the rate of discharge but might be decidedly influenced by the relative velocity of the liquid filling and the adjacent air.

Return to Streamlined Containers

Because of the excessive weight and drag of commercial-type containers, the employment of such containers for use as smoke tanks was discarded in 1935. The E6 series of tanks was a return to streamlined containers and the dynamic air-pressurized air inlet or vent, and incorporated improved discharge lines. The A-13 airplane was now obsolete, so that these tanks were developed for use on the A-17 series airplanes. The E6 tank was made of 18-gauge steel, was cylindrical in shape with ogival ends; it was 11½ inches in diameter and had a net filling capacity of 20 gallons. It was provided with an internal vent line similar to the E4 tank, rear filling plug, closure plate ejection spring, 5-inch discharge line and a bolted assembly for attaching the discharge line to the tank proper. The internal vent was eliminated in subsequent tanks and, in the E6R1, was replaced with a 2-inch poppet-type vent with an air scoop opening in a forward position. The E6R1 smoke tank was designed to provide a tank that could be filled at a depot, securely closed, stored for an indefinite period and then, when required, shipped to the proper location and quickly and safely prepared for use by the addition of necessary accessories. The discharge line was bolted to the tank flange and the outlet end was closed by an expendable metal closure plate. At 170 miles per hour, the tank discharged 20 gallons of filling in 4 seconds. The E6R3 tank was provided with a bevelled flange to which a mating flange of the discharge line was secured by means of a split ring clamp; a gasket between the two flanges forming a leak-proof joint. Subsequent models of the E6 series tank also incorporated this feature. The E6R3 tank was made of monel metal and incorporated the use of a new closure plate retaining system. This consisted of a U-shaped slide member which was attached to the closure plate and was operated by springs as soon as the closure plate was released by a rotating motion of the cylindrical cam attached to the operating shaft. This apparatus was intended for peacetime use in order to prevent the loss of the closure plate. In subsequent models of the tank, the thickness of the tank was reduced from 18 to 20 gauge, the diameter was changed from 11½ inches to 12½ inches, a 1-inch vent and then a 1½-inch vent were tried, and the complete apparatus was simplified for wartime use. The apparatus was considered expendable and the simplified discharge mechanism consisted of an expendable closure plate and a rotating operating shaft for releasing the plate.

The E6R7 tank incorporated a change from manual to spring operation with an attachment to permit its operation from a solenoid installed in the airplane near the undersurface of the wing directly above the discharge end of the tank. The tank was made of steel, had a total capacity of 23 gallons, and was similar in construction to its immediate predecessors (Figure 4). Tests of this apparatus indicated the need for a stronger operating spring, a longer operating shaft with a tightening spring at the forward end, and other improvements. A new type closure plate retaining mechanism, a heavier closure plate (case-hardened and fixed in position), a lengthened and case-hardened locking pin on the operating shaft, a safety latch for the operating lever, a shear wire for the safety latch, an operating lever guard, a safety pull wire assembly for the closure plate, a heavier operating shaft adjusting spring, and other improvements were incorporated in the E6R9 tank, which in all other respects was similar to the E6R7 tank. The closure plate retaining mechanism was provided only in cases where repeated use of the equipment was desired.

The Knife Cutter Tank

The Air Force was developing at this time, with the assistance of the Chemical Corps, a chemical tank of new design (Figure 5). This tank had a capacity of 20 gallons and a discharge time of 6½ seconds. The air scoop vent and the discharge were closed by thin metal diaphragms. These diaphragms were cut out by very sharp spring-operated cylindrical cutters, functioning in a manner similar to the can openers used by some service station attendants in opening cans of lubricating oil. The springs actuating the cutters were compressed by a special mechanism prior to assembly in the tank and held in the compressed position by a simple latch arrangement. This cutter mechanism was found to be rather dangerous; several serious injuries being sustained by personnel when the spring-compressing device or the retaining latch malfunctioned. During tests conducted at Edgewood Arsenal (now the Army Chemical Center), the tank functioned satisfactorily from a mechanical standpoint, but contamination of the tank and parts of the airplane was noted. This principle of operation was not used further in any tank development.

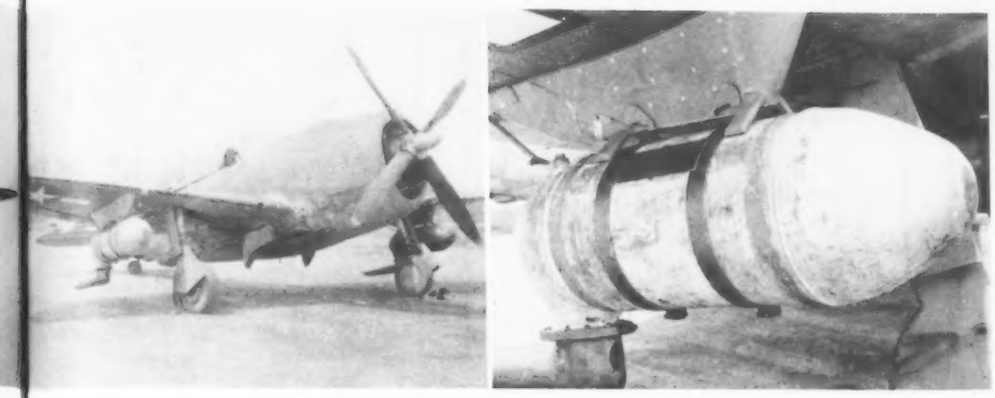


Fig. 9—M10 AND M33A1 TANKS ON F-47 AIRCRAFT
(Five pictures on left.)
Spray tank development has paralleled airplane progress

Efforts Toward Economy

Because of increased pressure from higher authority to economize and decrease the cost of operation of the War Department, efforts were made to simplify and make less expensive smoke tank equipment and to incorporate intermittent control devices so that the minimum amount of agent would be used in any training mission. No effort will be made to discuss this development except to describe one of the intermittent control devices which was developed. This apparatus installed on what is essentially an E6R9 tank is shown in Figure 6. The conventional air scoop vent, to which was attached a baffled cylindrical section to prevent the splashing of the contents through this opening, was employed and is shown in the photograph. The discharge mechanism consisted of a poppet valve actuated by a lever which permitted opening and closing the valve at will. Instead of the manual operation used in some of the previous types (not described), functioning of the valve was by means of a carbon dioxide operating device actuated by a solenoid. Electrical excitation of the solenoid caused it to open a valve, which permitted the compressed gas to enter the cylinder and exert pressure upon the end of the piston of the actuating mechanism. Movement of the piston acting through proper linkages opened the poppet valve. De-energizing the solenoid permitted the compressed gas to escape into the atmosphere with subsequent closing of the spring-loaded discharge valve. Opening of air scoop vent valve was accomplished when the solenoid was initially energized. Sufficient carbon dioxide was contained in the cylinder to permit the operation of the mechanism a sufficent number of times to obtain complete discharge of the container.

Tanks with Frangible Closure Plates

In 1938 tests were conducted with glass closure plates in the discharge line and air inlet, using electric detonators fired from the 12-volt circuit on the airplane to shatter the glass closures. This tank, constructed from the body of an E6R9 tank, was designated the E9 tank. In order to avoid the use of the two detonators on the tank, a swinging type check valve was substituted for the glass plate in the vent. The check valve permitted fumes to escape when FS was used in the tank and caused some contamination of the bomb rack when simulated chemical agents were sprayed. The design of a new spring-operated vent line was undertaken but was subsequently abandoned in favor of the use of the glass closure and the detonator. At airplane speeds of approximately 180 miles per hour, this tank discharged its contents of 22 gallons of agent in 5 seconds, giving a spray release path approximately 440 yards in length with a distribution of approximately ½ lb. of material per linear yard per tank. Tanks of larger capacity, even as large as 40 gallons, were considered. The E9R4 tank developed in 1940 was made 12 inches longer than the E9R3, which was an E9 tank with a modified discharge line, and had a capacity of approximately 30 gallons. The thickness of the steel used in the tank was increased from 20 to 18 gauge. In order to eliminate contamination of the airplane when these tanks were carried on twin-engine airplanes (such as the XA-21), it was necessary to increase the length of the discharge line 8 inches longer than the discharge line for the E9R3 tank. The tare weight of the tank was 55 lbs. At air speeds of 250 to 270 miles per hour, discharge time varied from 4½ to 6 seconds. Several minor modifications, such as adding a conical section or straightening vanes to the discharge line, were tried in an effort to decrease the effect of air turbulence on liquid shatter and improve the drop size.

Emphasis on Streamlining

As airplane speeds became higher and higher, it soon became apparent that the aerodynamic design of externally mounted smoke tanks would have to be improved. Several modifications were made in the E9R4 tank to improve the streamlining, some of these modifications later being incorporated in new designs of spray tanks. It was felt at that time that to obtain optimum streamlining of the container suspended from a bomb rack it was necessary to fair in the tank contour with the wing surfaces. Since drag is directly proportional to the frontal area, consideration was given to a tank design which would bring the top of the tank flush with the under surface of the wing at the suspension point. The E10 tank, as designed, had a flat top and was similar in cross-sectional shape to the hull of a ship. This design did not permit the use of the conventional type of air inlet vent because of structural interference with the wing surface. The air inlet consisted of a flared inlet near the forward end of the tank leading to a vent pipe inside and extending through the liquid to the air space above the liquid level, with a protecting sleeve attached to the top of the tank to prevent contamination through the pipe. Construction of a preliminary model of the streamlined container of the tank was made but the complete tank was never finished.

Continued study of the streamlined tank problem resulted in the conclusion that a deeper, slimmer shape might be more desirable as far as minimum drag and minimum airplane contamination was concerned. Consequently work was begun on a new tank embodying these new ideas. The top of the E10R1 tank was flat, though not tangent to the wing surface of the airplane. The cross-section below the top was approximately half of an ellipse, and an attempt was made to streamline the entire container as much as possible. The discharge line

(Continued on page 32)

SHIELDS FOR GAMMA RADIATION

By Donald H. Hale, Ph.D.
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Gamma radiation arises in the atomic explosion. When one pound of uranium-235 undergoes fission about 50 milligrams mass-equivalent (or 3×10^{25} Mev) of energy appears as radiation. This is largely gamma radiation and one part appears during the actual fission of the uranium and another, and larger part, arises in the decay of the radioactive fission products which are produced by the fission reaction. This gamma radiation is a distinct hazard and an understanding of its interaction with matter is basic to estimating the shielding properties of various construction materials and the effects of the radiation upon the human system.

Gamma radiation arises from the following sources:

1. Neutron-gamma (n, γ) reactions
2. Radioactivity induced in materials
3. The fission process
4. Decay of radioactive fission products

The atomic explosion releases a large number of free neutrons and these are available for the reactions listed in 1 and 2 above.

An example of the neutron-gamma reaction is furnished by the capture of a neutron by the nucleus of a copper atom as follows:

$$Cu^{63} + n^1 \longrightarrow Cu^{64} + \text{gamma photon}$$

The excess energy of the capture reaction is radiated as a gamma photon as shown by the equation above.

Neutron capture can lead to the formation of radioactive atoms in construction materials. These radioactive atoms emit gamma radiation when they decay. This is a form of induced radioactivity. An example of this type of reaction is given by the following equation:

$$Ni^{62} + n^1 \longrightarrow Co^{62} + H^1$$

This equation shows that a neutron is captured by an atom of nickel-62 and this causes the ejection of a proton and yields an atom of cobalt-62. The cobalt-62 is radioactive and decays as follows:

$$Co^{62} \longrightarrow Ni^{62} + e^0 + \text{gamma photon}$$

This equation states that the atom of radioactive Co^{62} decays by the emission of an electron and a gamma photon. The half-life for this particular decay reaction is 1.75 hours and the gamma photon has 1.3 Mev (million-electron-volts) energy.

Many reactions of this type are known and such reactions can induce radioactivity in construction materials. However the capture cross sections of atomic nuclei for neutrons for this type of reaction are not large. This means that the probability for such reactions is low and one does not, therefore, expect to find much induced radioactivity after an atomic explosion due to such reactions.

Fission is induced when an atom of uranium-235 or plutonium-239 captures a neutron as is shown by the following equation:

$$U^{235} + n^1 \longrightarrow Y^{97} + I^{136} + 3n^1 + \text{energy}$$

The total energy released when one such atom undergoes fission is about 180 Mev and of this about 15 Mev is gamma radiation. A part of the gamma radiation appears during the actual fission of the atom. This gamma radiation is quite intense but is of short duration. It is a hazard to unshielded personnel out to a considerable distance from the zero point for the explosion.

The total gamma radiation emitted by the fission products is greater than that emitted during the actual fission of the bomb. The uranium, or plutonium, nucleus does not always split in the fission process so as to yield Y^{97} and I^{136} as shown in the above equation. It appears that there are a number of ways in which these atoms can split and there are, therefore, a large number of possible fission fragments. Actually over 200 of these fission fragments, or fission product atoms, have been identified. Almost all of them are radioactive and decay by the emission of high speed electrons (beta particles) and gamma photons. Thus it is known that yttrium-97 is produced in the fission of uranium, that it is radioactive and that it decays as follows:

$$Y^{97} \longrightarrow Zr^{97} \longrightarrow Cb^{97} \longrightarrow Mo^{97}$$

The radioactive atom of yttrium-97 decays in three steps to become a stable atom of molybdenum-97 and in each step a beta particle and a gamma photon are emitted. Another example is furnished by the radioactive atom of xenon-144 which is produced in the fission process and which decays as follows:

$$Xe^{144} \longrightarrow Cs^{144} \longrightarrow Ba^{144} \longrightarrow La^{144} \longrightarrow Ce^{144} \longrightarrow Pr^{144} \longrightarrow Nd^{144}$$

The equation shows that xenon-144 decays in six steps to become stable neodymium-144 and in the process six gamma photons are emitted. Each of the decay steps has its own characteristic half-life. Most of the half-lives are quite short but some are long. Thus the half-life for the decay step, Ce $\longrightarrow$ Pr, is 275 days. It is therefore apparent that after an atomic explosion there will be a considerable amount of delayed radioactivity due to the presence of radioactive fission products. This radioactivity will decrease with time, due to the decay process, and will fall off quite rapidly during the minutes immediately after the explosion but one must expect some radioactivity for a long period of time following an explosion. If the explosion takes place in the air this type of hazard will be reduced due to the fact that the heated air will cause an updraft which will sweep many of the radioactive fission products high into the air. If the burst takes place

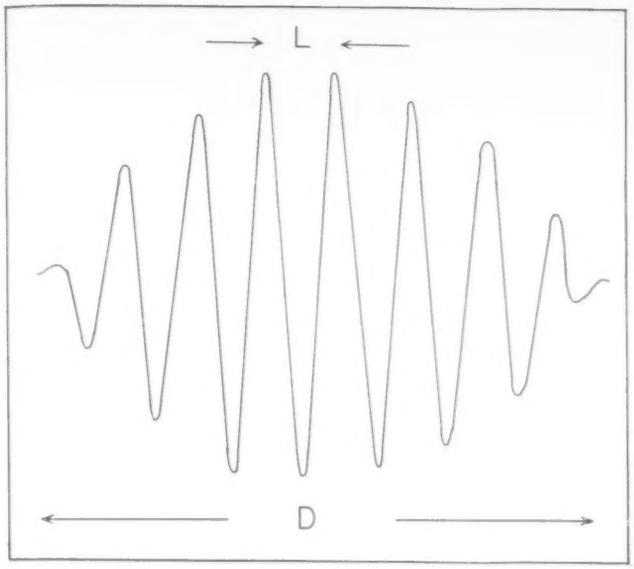


Fig. 1—Representation of the gamma photon

under the surface of the sea or land most of the fission products will be trapped and a high radiation intensity must be expected in the vicinity of the zero point.

The gamma photon is electromagnetic in character as are the photons of visible, infrared and ultraviolet light and x-rays. It may be pictured as an electromagnetic wave train or impulse as shown in Figure *1*. The wave length L is given by the wave equation:

$$Lf = c$$

where f is the frequency and c is the velocity of light. The frequency f is given by:

$$E = hf$$

where E is the photon energy, measured in ergs, and h is Planck's constant which has the value, $h = 6.6 \times 10^{-27}$ erg-sec.

If the energy of the photon is known its wave length can be calculated. In atomic physics work the energy of the photon is normally expressed in millions of electron-volts rather than in ergs. If the energy of the photon is given in millions of electron-volts the relationship between energy and wave length becomes:

$$L = \frac{1.24 \times 10^{-10}\ \text{cm}}{E}$$

Therefore, for a photon of 2 Mex energy:

$$L = \frac{1.24 \times 10^{-10}\ \text{cm}}{2} = 6.2 \times 10^{-11}\ \text{cm} = 6.2 \times 10^{3}\ \text{angstrom units}$$

The wave length of the photon is a matter of some importance since the manner in which the photon interacts with matter is different for photons of different wave lengths.

The human eye responds to visible light which is composed of electromagnetic photons which lie in the range of wave lengths from about 4,000 to about 8,000 angstrom units. It is apparent therefore that the gamma photon is much more energetic and has a much shorter wave length than do the photons of visible light.

The gamma photons which arise in the fission process and which are being considered here have energies in the range of from about 0.5 Mev to about 5 Mev. The length of the wave train (D of Figure *1*) for such photons is about 0.2 mm. The radius of the atomic nucleus is of the order of 1×10^{-12} and the length of the wave train is many times the radius of atomic nucleus.

There are several mechanisms by which gamma radiation may interact with matter and be degraded; i.e. lose energy, or be absorbed. The more important of these are as follows:

Manner of interaction	*Interacts with*	*Important in*
Photoelectric effect	atomic electron	heavy materials.
Compton effect	unbound electron	nearly independent of material.
Pair production	nuclear field	heavy materials, above 5 Mev energy; light materials, above 10 Mev energy.

In the photoelectric effect the gamma photon interacts as a wave with the absorbing atom. As a result of the interaction the photon is absorbed and an atomic electron receives all of the energy of the photon and is ejected from its orbit within the atom. Generally the electron is ejected from the K or L shell. It is ejected with energy E_e as given by the following equation:

$$E_e = E_p - B$$

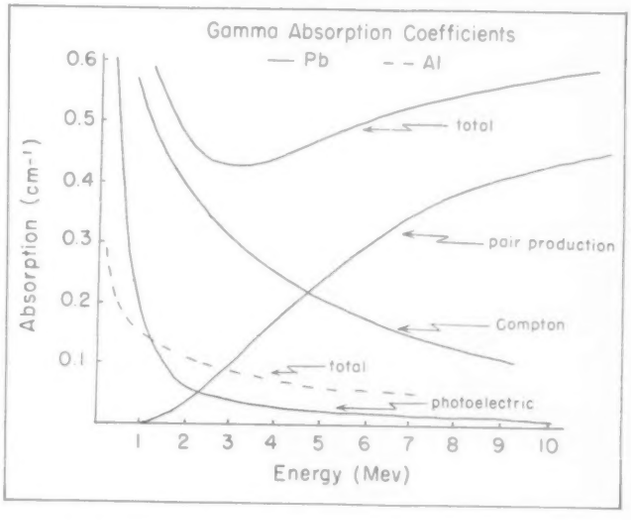
That is, the electron is ejected with energy E_e which is equal to the energy E_p of the absorbed photon less the energy B which binds it to the atomic nucleus. Following this process the atom is left with one electronic orbit vacant. This is filled by a free electron falling into the vacant electronic orbit and this causes the emission of one or more x-ray photons. The total energy of the several x-ray photons emitted is equal to the energy of the absorbed gamma photon but the energy of any one x-ray photon is generally much less than that of the gamma photon. This, then, is a degrading process; i.e. the wave length of the radiation is increased in the process.

The atomic cross section for photoelectric absorption varies directly, and roughly, with the density of the absorbing material as follows:

Absorption Cross Section = Constant $(1/E)^{3.5} Z^4$ cm^2

where E is the energy of the absorbed photon and Z is the number of atomic electrons for the absorbing material. Since the atomic cross section, and therefore the probability of absorption, varies directly with the fourth power of Z it is obvious that the photoelectric effect is much more important in the heavier materials.

Fig. 2—Variation of the linear absorption coefficients with photon energy for lead and aluminum



The photoelectric absorption varies inversely with the 2.8th power of the photon energy and, for any given material, the effect falls off rapidly with increasing photon energy. This is shown in Figure 2. The effect is, therefore, important for the heavier materials and for photon energies of less than about 1.5 Mev.

In the Compton process an elastic collision occurs between a gamma photon and a single unbound electron. Momentum and energy are conserved in the process. The photon gives up a part of its energy to the electron and the electron recoils with considerable energy. The photon acts, in this process, as if it were a small body and also recoils. However, since the photon has given up a part of its energy to the electron the recoil photon has less energy and a longer wave length than did the original impacting photon. In this process the photon energy is degraded; i.e. the photon is not absorbed but it does lose a part of its energy. The process is indicated in Figure 3. The change in the wave length of the photon is given by:

$$\Delta L = (h/m_o c)\ (1 - \cos A)$$

where m_o is the mass of the electron and A is the recoil angle for the deflected photon. If $A = 180°$ the change in photon energy and wave length is a maximum. For this condition the maximum energy is transmitted to the electron. The energy of the recoil photon for those collisions for which $A = 180°$ is given by:

$$E_p' = \frac{E_p}{1 + 3.9E_p}$$

Where E_p' is the energy of the recoil photon. Thus, for a photon of 1 Mev energy:

$$E_p' = \frac{1}{1 + 3.9} = 0.204 \text{ Mev}$$

The kinetic energy of the recoil electron is given by:

$$E_e = E_p - E_p' = (1 - 0.204) = 0.796 \text{ Mev}$$

The probability for Compton scattering decreases with increasing photon energy and increases with the density of unbound electrons in the absorbing material. The electron density increases slowly with increasing atomic number and the most dense materials have an electron density about 30% greater than that of the lightest materials. Therefore, for all practical purposes, it may be assumed that the probability for Compton scattering is the same for all materials for photons of the same energy.

The probability for Compton scattering decreases with increasing photon energy and the process is comparatively in effective for photons with energies greater than about 4 Mev. This variation with photon energy is shown in Figure 3.

A gamma photon may be absorbed and produce an electron pair; i.e. a positive and a negative electron. The process occurs in the close proximity of, but not in, an atomic nucleus. The energy equivalent law demands that the photon must have energy in excess of 1.02 Mev if the process is to be possible. This can be shown as follows:

$$E = mc^2 = 2(m_o c^2) = 1.02 \text{ Mev}$$

where m_o is the mass of the electron.

In this process the photon disappears and if it has energy in excess of 1.02 Mev the excess energy appears as kinetic energy of the electrons. If a 2 Mev photon produces an electron pair the electrons share kinetic energy in the amount of $2 - 1.02 = 0.98$ Mev. The electrons share this kinetic energy equally.

The probability for pair production increases as the second power of Z and this process, therefore, is important in the heavier materials. Also, the probability increases for increasing photon energy. In lead, the absorption of gamma energy by pair production becomes equal to that due to the Compton effect at 4.75 Mev and at the higher energies the pair production effect becomes the important process. This is shown in Figure 3. In aluminum, and other light materials, the pair production process does not become important until photon energies exceed about 10 Mev.

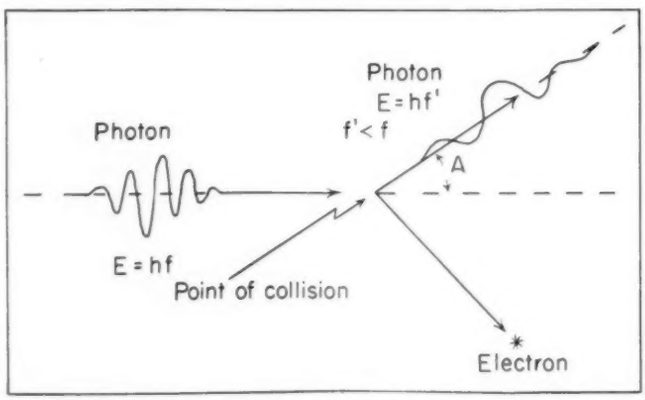
The linear absorption coefficient is found for any of the three processes, for any material and for photons of any energy by multiplying the cross section for the process by the number of atoms per cubic centimeter for the material under consideration. A total linear absorption coefficient for all three processes is defined by:

$$a = p + c + k$$

where a is the total linear coefficient and p, c and k are the absorption coefficients for the photoelectric effect, the Compton effect and pair production. In Figure 3 the total linear absorption coefficient is plotted as a function of photon energy for lead and aluminum. It is to be noted that the curve for lead shows a minimum at about 3 Mev. This indicates that less thickness of lead is required for shielding against the photons of high energy or low energy.

Assume that a colliminated beam of gamma radiation impignes upon a slab of absorbing material as shown in Figure 4. Assume that the intensity of radiation in the beam is I_o before penetration and that after penetration the intensity is I. Also, I is less than I_o due to the fact that the processes discussed above operate to absorb and

Fig. 3—Illustration of the Compton effect



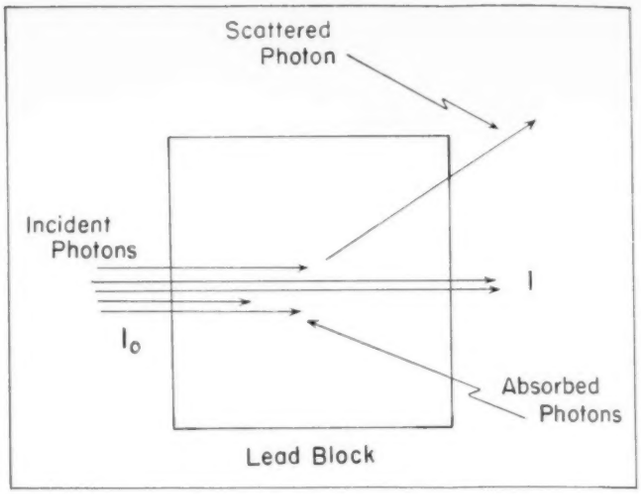


Fig. 4—Illustration of the method of determining the linear absorption coefficient by measuring I_o and I

scatter photons. The relationship between I and I_o is given by:

$$I = I_o e^{-ax}$$

where a is the total linear absorption coefficient and x is the thickness of the absorber. For lead and photons of 3 Mev energy $a = 0.44\ cm^{-1}$. The thickness of lead required to reduce the intensity of the beam by 99 percent can be calculated as follows:

$$0.01 = e^{-0.44x}, \text{ and } x = 10.5 \text{ cm}$$

As is shown by Figure 4 the photon that is scattered out of the colliminated beam is treated as if it were absorbed in the above discussion of the absorption coefficients. This can lead to serious errors in shielding calculations since the photon may be scattered from the beam and then, by a second scattering, reach the body of the individual whom the shield was designed to protect. As is shown in Figure 5, shadow shields are often used. The thickness of shielding required to protect the worker from direct radiation is calculated but this can lead to serious errors since, as is shown by Figure 5, photons may be scattered within the shield or by the atoms of surrounding materials in such a manner that they reach the observer. The simple theory discussed above does not account for scattered photons and the values for the linear absorption coefficients which appear in the various tables, and which were experimentally determined, are too small. Stated conversely, this means that if one uses these values he will come out with a value for the required shielding thickness which is too small.

In theory any number of scatterings due to the Compton process can be taken into account and an absolute value for the absorption coefficient calculated. In practice, if more than two scatterings due to the Compton process are included the calculations become very tedious. Hirschfelder and Adams[1] have made such calculations for a few materials. Some of their values of the required thickness of lead and iron to reduce the intensity of gamma radiation of different energies by various amounts, are shown in the table below.

		Required Thickness of Shielding in Centimeters		
	Ratio $I/I_o =$	0.10	0.01	0.001
Lead	1 Mev	4.23	8.11	11.91
	3 Mev	6.88	13.27	19.45
Iron	1 Mev	7.22	13.31	19.08
	3 Mev	11.11	21.00	30.46

A study of the required shielding thickness to produce the various attenuations in the gamma intensity, as shown in the table, indicates that when more than one Compton scattering is taken into account the absorption coefficient is no longer linear. This means that the coefficient is no longer independent of the shield thickness. One can calculate an average value for the absorption coefficient for each shield thickness given in the table. The results of such a calculation are shown in the table below for 1 Mev photons in lead.

Ratio $I/I_o =$	0.10	0.01	0.001
Shield Thickness	4.23 cm	8.11 cm	11.91 cm
Absorption Coefficient	0.545 cm^{-1}	0.568 cm^{-1}	0.580 cm^{-1}

It is often necessary to make a rough estimate of shielding requirements. The attenuation of gamma radiation in the range of energies of interest in this work can be estimated by use of the following approximation equations.

For lead, $A = I/I_o = 10^{-x/5}$, where x is the shield thickness in centimeters.

For concrete, $A = I/I_o = 10^{-x}$, where x is the shield thickness in feet.

Assume that it is desired to estimate the thickness of a lead shield which would reduce the intensity of the gamma radiation from an atomic explosion or pile by 99 percent. The approximation equation could be used as follows:

$$A = I/I_o = 0.01 = 10^{-x/5}$$

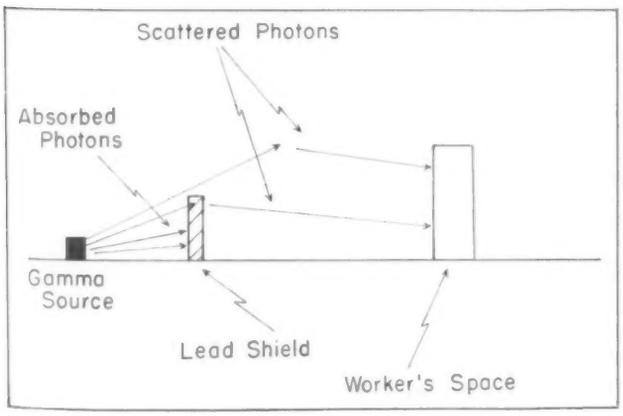
and $$\log 100 = x/5 = 2$$

or, $$x = 10 \text{ cm}$$

This value for the shield thickness agrees fairly well with the value of Hirschfelder and Adams as given in the table above.

[1] Hirschfelder and Adams, Physical Review 73, 863 (1948)

Fig. 5—The shadow shield



THE LIGHTER SIDE

IT HAS BEEN SAID

Citizen: "I wouldn't vote for you if you were St. Peter himself."

Candidate: "If I were St. Peter, my friend, you wouldn't be in my precinct."

* * *

"Where'd you-all get dat derby hat?"

"Hit's a su'prise fum mah wife."

"A su'prise?"

"Yeah, ah cums home de odder night unexpected an' found it on the table."

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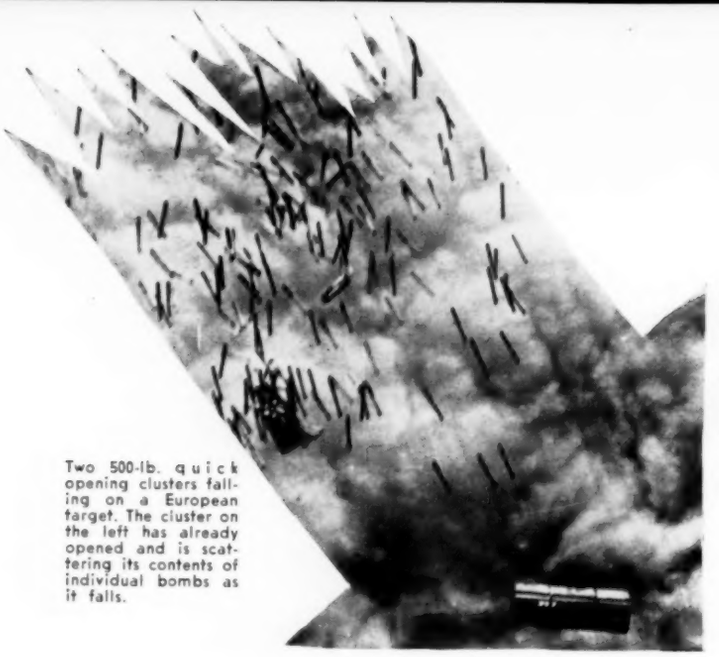


Two 500-lb. quick opening clusters falling on a European target. The cluster on the left has already opened and is scattering its contents of individual bombs as it falls.

PACKING INCENDIARY BOMB CLUSTERS

A CONTAINER PROBLEM

By Fred B. Shaw, Jr.
Chief, Engineering Division
Technical Command
Army Chemical Center

In the early phases of the recent war, incendiary bombs were limited in their use almost exclusively to the European and Mediterranean Theaters of Operations, where it is interesting to note, they were credited with 70% of bomb damage in many large enemy cities as compared with 30% for high-explosive bombs. At first, because of the nature of European-type targets, 100- and 500-pound quick-opening clusters of four-pound magnesium or thermite bombs (Fig. 5) were standard, though eventually a 500-pound aimable, delayed-opening cluster of 110 four-pound magnesium bombs (Fig. 7) was found to be desirable and, in general, superseded the quick-opening or scatter-type clusters.

Since the sturdy, compact four-pound magnesium bomb and its relatively simple fuze were essentially moistureproof, and could withstand adverse weather conditions for limited periods of time even without additional protection, and since the temperate climate of Europe was not nearly as severe as that experienced in the tropical Pacific, the packing of the cylindrically shaped, scatter-type clusters presented little difficulty. Adequate physical and atmospheric protection were attained by using conventional style 2-nailed wood boxes constructed in accordance with U. S. Army Specification 100-14 and provided with sealed duplexed sisal-kraft and fiberboard liners.

The packing of the aimable type of cluster presented more of a problem because its large and comparatively fragile tail assembly had an effective diameter several inches greater than that of the main cluster body. Since the packing of both the removable tail and the cluster body in one container was required by the Air Forces, the maximum savings in cubage to be attained by the use of separate boxes or crates for the two sub-assemblies were not possible, and other means of approaching this minimum cubage had to be developed.

Initially, a two-compartment modified style 2 box was used (Fig. 3). The cluster body in an asphalt-laminated fiber drum sealed with a waterproof tape, or in a light-gage, full-opening head, steel drum, occupied one compartment, and the tail was so positioned in the other compartment so as to cause its maximum dimensions to coincide with the diagonal dimensions of that space. Necessary cluster fuzes and arming wires, in individual waterproof packages, were placed in the same section with the tail. Even then, however, considerable unused space, and therefore excessive cube and weight, resulted.

Because of the tremendous importance of reducing the cube and weight of military packs, experimentation was continued and eventually an open-type, cylindrical crate (Fig. 9) was evolved. This container, though slightly weaker than the two-compartment box, proved to be unexpectedly sturdy in transoceanic shipments. Because of its 15.1 cubic feet and 560 pounds gross packed weight, as compared to the previous 18.0 cubic feet and 625 pounds, and in view of its greatly decreased lumber requirements, it was adopted as the standard pack for 500-pound clusters of the M50 (four-pound magnesium) bombs destined for European targets.

Meanwhile, the development of an incendiary bomb suitable for Pacific, and particularly Japanese, type targets had been vigorously pursued by both the National Defense Research Council and the Chemical Warfare Service. Two bombs, the M69 and the M74, having a gross filled weight of approximately 6 and 10 pounds respectively, resulted from this work. Both were somewhat similar in exterior appearance, both functioned primarily by throwing a mass of flaming gellied gasoline or modified asphalt onto the target, and both were considerably more susceptible to physical and atmospheric damage than the M50. The M69, which was produced in by far the greater quantity of the two, was especially liable to moisture damage since its non-moistureproof fuze contained a black powder element. To further complicate the packing problem, these bombs were assembled 38 to a so-called 500-pound aimable cluster which had a non-removable tail of greater effective diameter than the cluster body (Fig. 4).

Because of the peculiar attributes of the individual bombs and of the cluster itself, and due to the hot, humid climate through and in which it was necessary to ship and to store them, an unusually large, rigid, moisture-vaporproof container was imperative. The requirements for minimum weight and cube, of course, still prevailed.

The use of the so-called moisture-vaporproof film barrier material was impossible for several reasons. First, the rough cluster with its many sharp projections made necessary the use of large amounts of protective materials between the cluster and the moisture-vaporproof film, and this resulted in too great a total cubage. Secondly, such an exacting and tedious packing method was not compatible with the tremendous production rates which had to be maintained. Lastly, the amounts of dehydrating agent re-

quired by this application of the moisture-vaporproof film type of package, in view of the larger volume of space and dunnage packed with each cluster and the millions of units involved, was just not available. In fact, not even a small percentage of it was available.

It was therefore concluded that the use of a container constructed from completely non-moisture transmitting materials and equipped with almost perfect seals would be necessary. As a further complication, because of the urgency of the program, practically no time could be allowed for the construction of complicated tools or dies. The initial container, at least, had to be capable of being subject to mass production with the use of only relatively simple jigs and tools.

Under these circumstances, the use of the newly developed metalclad plywood-type box (Fig. 2) appeared to be a logical solution to the problem. The thin, closely bonded metal sheath that formed the interior of such containers, especially when all contacting surfaces except for those associated with the closures were soldered, seemed to promise a practically hermetically sealed container.

Using such boxes equipped with a bolted closure and making use of an asphaltic type gasket material (Permagum B-40) at the closure, experimental packs were made up and on testing proved to comply with all the requirements. By using exceptionally dry wood braces to secure the clusters in position within the boxes, and by sweeping each pack with dry air (by means of suitable fittings) immediately after closure, it was found possible to maintain a very low humidity within the boxes for long periods of time without making use of any dehydrating agent, even though the packed boxes were subject to severe rough handling.

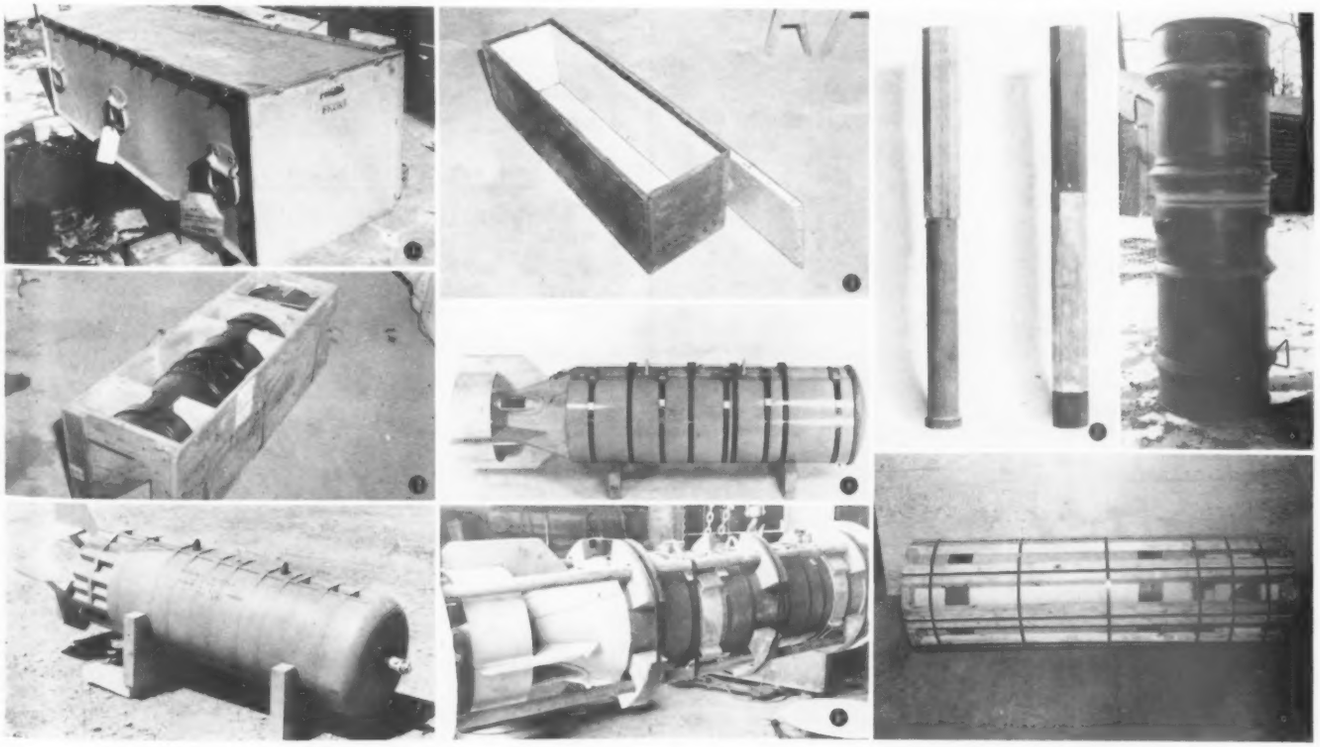
However, production troubles soon showed that a sufficient quantity of these metal-bonded plywood boxes would not be available when needed, in spite of the relative simplicity of the manufacturing jigs and tools required. So an equivalent all-steel box (Fig. 1) was approved as an alternate on the basis of tests. Except for the tremendous increase in weight, this type of container exhibited most all of the qualities of the metal-bonded plywood box.

But before long, unfortunately, both these containers proved to be inadequate for the job, not because of any inherent qualities, but because the unskilled labor available to their manufacturers, and the lack of experience with such novel boxes by all concerned, resulted in inexact cutting and assembly. Since very close tolerances were essential in order to obtain completely moisture-vaporproof assemblies, a significant percentage of the containers were found to be worthless for the intended use. Such faulty containers, instead of protecting their contents, were allowing the accumulation of moisture; for an almost completely sealed box will allow the entrance of moisture much more readily than it will allow its escape. This resulted in high humidities within the packs, and the resultant corrosion of bombs and inactivation of the individual bomb fuzes. It was therefore essential that a more foolproof container be devised.

Meanwhile, fortunately, a steel drum-type of pack had been developed, and tooling up for its production had been in progress. The container for this pack (Fig. 6) consisted essentially of two 20-inch inside diameter, 18-gauge steel drums, each open at one end, and one of which was provided with a 20-inch outside diameter "collar" at its open end. These drums were slipped over the ends of the cluster (after it had been provided with the minimum essential dunnage required to brace it inside the drums and thus protect the cluster in case of rough handling of the pack). The sealing of this pack was then accomplished by the use of a continuous, 1-inch thick, sponge rubber gasket between the two drums at the point at which they contacted and

(Continued on page 40)

1. All steel box for one 500-pound cluster. 2. Metal-bonded plywood box used as container for 500 pound clusters. 3. The sturdy two-compartment type container. 4. M20 500-pound aimable cluster containing 38 M74 bombs (note larger diameter of tail relative to cluster body). 5. Four-pound incendiary bombs. 6. Steel drum used for packing one 500-pound aimable cluster. 7. M17 500-pound aimable cluster containing 110 M50-type bombs. 8. One system of bracing of a 500-pound cluster prior to packing in the standard steel drum. 9. Cylindrical crate type of container.



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First To Hit Class "A"

The 390th Chemical Laboratory Company, a reserve unit affiliated with the Carbide and Carbon Chemicals Corporation of Texas City, Texas, is the first Chemical Corps organization to achieve class "A" status in the ORC.

To achieve this status a unit must have an active membership of 80 to 100 percent of the officers and 40 to 50 percent of the enlisted men called for by its Table of Organization and Equipment. In view of its expansion to the Class "A" category, the 390th is now authorized seven officers, two Warrant Officers and twenty to twenty-five enlisted men.

Many of those in the unit employed by the sponsoring company and other industrial firms work on jobs corresponding to Laboratory Company specialties.

In addition to the usual military specialties, the 390th's T/O calls for a Laboratory Director, Chemical Research Engineer, Analytical and Organic Chemists, a Toxicologist, Translator and Intelligence Officer, Chemical Engineer, Ground Munitions Workers, A Glassblower, Draftsman, Librarian, Photographer, Chemical and Physics Laboratory assistants and Toxic Gas Handlers.

FOR THE RECORD

A CORRECTION

The paper entitled, "The Filtration Law for Aerosols," by Dr. S. H. Katz, which appeared in the January issue of the JOURNAL, contained certain typographical errors in the mathematical equations shown at the bottom of the right-hand column on page 14. The printer of the JOURNAL was unable to obtain the proper linotype mats and did the best he could to set the equations in standard type. Unfortunately, the result was not too good and the editors extend apologies to Dr. Katz and reproduce below the equations as they should have appeared originally.

Equivalence of Equations /2/, /5/ and /6/

According to definitions:

$$Q = \frac{N}{N_o} \qquad /7/$$

Then, after substitutions in equations /2/ and /6/

$$q^p = e^{-kL} \qquad /8/$$

Or: $$q = e^{-kL/p} \qquad /9/$$

And: $$\text{Log}_e q = -kL/p \qquad /10/$$

Transposing: $$k = \frac{-p}{L} \text{Log}_e q = \frac{-p}{\Delta X} \text{Log}_e q \qquad /11/$$

By substituting this value of k in /5/, the equation /5/ may be reduced to equation /2/:

$$\text{Log}_e \frac{N}{N_o} = -\left(\frac{-p}{\Delta X} \text{Log}_e q\right) \Delta X \qquad /12/$$

Or: $$\text{Log}_e \frac{N}{N_o} = p \text{Log}_e q \qquad /13/$$

And: $$\frac{N}{N_o} = q^p = Q \qquad /2/$$

Chemical Corps Training

A practical demonstration of the spirit of cooperation which exists in the Chicago area amongst industry, the Army and AFCA in the training program of Chemical Corps reserve personnel was a gas mask manufacturing and assembly plant tour conducted April 3 by all CC Reservists in Chicago. The plant of the Acme Protection Equipment Company was made available to the 5409th ORC Service Unit through courtesy of Mr. G. M. Glidden, company president, who also serves as president of the Chicago Chapter, AFCA.

THIS IS HOW!—President G. M. Glidden demonstrates for witnessing Reserve officers the gas mask face piece assembly operation in his Chicago plant.

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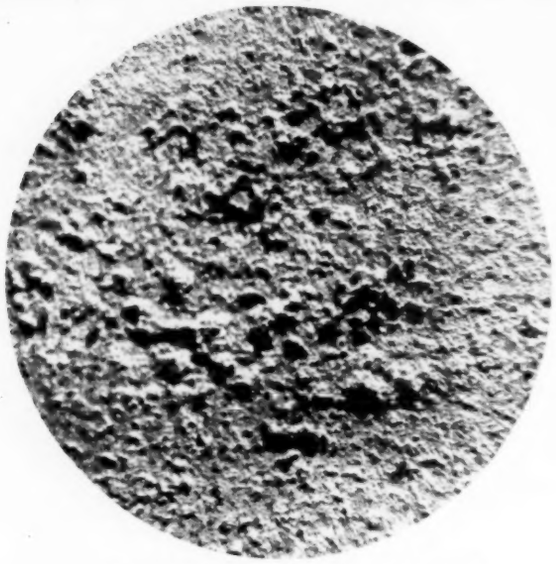


ALUMINUM CANISTER FOR GAS MASK
Photomicrograph showing internal surface corrosion caused by mustard gas

CORROSION PROBLEMS OF THE CHEMICAL CORPS*

By Jack Furrer
Engineering Division, Technical Command
Army Chemical Center

Our present corrosion research in the Chemical Corps is not confined and pursued under one research program, but is scattered throughout the various divisions of the Technical Command due to the diversity of our work. While there is some similarity between the various individual projects, each requires a different approach and solution. This leads, therefore, to the discussion of numerous individual problems rather than one broad subject.

In common with all technical services manufacturing, storing, and shipping mechanical material, the Chemical Corps has numerous problems involving the prevention of corrosion of metal surfaces. However, corrosion problems peculiar to the Chemical Corps are primarily due, not to moisture, but to the action of chemical agents.

For this discussion, I have chosen a number of problems which I believe to be of interest and I shall attempt to point out the actual component impurity of decomposition product which is considered to be the corroding agent.

One item of protective equipment which is fabricated of aluminum to obtain the lowest possible weight, requires protection internally from hydrochloric acid and free chlorine when in use. In addition, severe crimping and seaming are required to form the unit.

As is apparent, the problem resolved itself into the development of a high flexible film that could be worked without fracturing and at the same time give sufficient protection to the aluminum against these corrosive agents.

The basic program was divided into three parts, namely, the investigation of surface treatments, primers, and top coating compounds, separately, and in combination.

To simplify the procedure, 2-inch by 4-inch panels of 52S-O aluminum were used. They were tested by immersion in the material that generated the hydrochloric acid and chlorine. Duplicates of all panels were run with the edges waxed.

The metal treatments chosen were those most widely used in industry and consisted of the following:

1. Vapor degreasing.
2. Alkali cleaning.
3. Cold phosphoric acid treatment.
4. Hot phosphoric acid treatment.
5. Anodizing.
6. Alroc No. 12 treatment.

The primers used were vinyl "wash" (a pigmented vinyl composition developed by Watson Standard Co.), zinc chromate, vinyl blue lead, and sodium phenolate vinyl. These were chosen on the basis of past performance in regard to acid resistance.

The top coats were selected from the following classes of materials which, it was believed, would offer the greatest protection to aluminum:

1. Phenolic resins.
2. Phenolic chinawood resins.
3. Chinawood oil alkyds.
4. Clear vinyls.
5. Rubber base resins.
6. Vinylidene chloride.
7. Cyclized rubber.

The results of this phase of the investigation demonstrated that:

1. The Alroc treatment greatly increased the corrosion resistance of the aluminum and, contrary to popular opinion, withstood the necessary fabrication involved when run on standard equipment.

2. The use of primers did not add appreciably to the resistance of the aluminum, particularly when the Alroc process was used as a surface treatment.

3. Two thin top coats gave approximately the same protection as a primer and a top coat.

4. Phenolic coatings were most satisfactory but they would not withstand severe forming and therefore vinyl coatings were recommended for those parts that were to be worked.

5. Pigmentation increased the resistance to some extent.

The final coats chosen as a result of this investigation were of the approximate formulation:

For the phenolic:

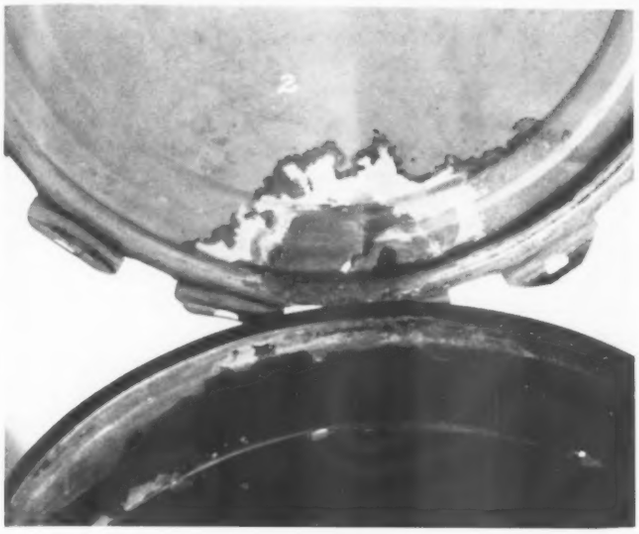
78% Phenolic—Amberol PR87
14% Pigment—Chrome Oxide, Carbon Black, Lead Oxide and China Clay

and for the vinyl:

65.5% Vinyl Chloride Acetate Copolymer
34.5% Pigment—Chrome Oxide, Carbon Black and Lead Oxide.

The above systems used over the Alroc treatment with

*Presented before "Symposium on Corrosion" sponsored by the Corrosion Subcommittee of the Deterioration Prevention Committee at the National Academy of Science and before the 2991 Research and Development Training Group of the ORC.



AN EXAMPLE

Perforation of RH-195 compartment of unit, DANC solution, M4 due to the corrosive action of the agent

two thin coats (total thickness 0.0015 inch) have given the best protection to date but still fall short of the desired standards.

In the future we intend to extend the work on the more promising compounds found by this previous work, investigate some of the newer coating systems and test the practicability of polyethlene liners.

For many years it has been known that mustard gas is extremely corrosive towards steel artillery and mortar shell, particularly at high temperature. Repeated tests have led us to believe that its corrosive action is due to two agents—first, the presence of over-chlorinated polysulfides, and second, the degradation product at 150°F., hydrochloric acid.

During the past war extensive research had shown that phenolic coatings on the inside of shell gave reasonably good protection, but that from a coat standpoint it would be more desirable to use an additive which would inhibit this corrosive action.

A literatire survey showed little information regarding the stabilization of organic liquids. It had been prevously reported that ammonia would tend to stabilize Levinstein mustard gas as well as precipitate the excess sulfur present. The initial research was guided by the fact that amines were known to be good stabilizers for compounds that liberate hydrochloric acid.

Experiments with a wide variety of amines gave disappointing results until hexamine was tried. Hexamine gave better results than any previous compound, but its stabilizing action was as a depressant on gas development, and it did not inhibit the chemical decomposition to a significant degree.

The problem of obtaning a suitable container for calcium hypochlorite bleach and semi-stable chlorinated compounds has been with us for a long time. It is necessary that these materials be shipped to all Theaters of Operations and they should remain in usable condition after long periods of storage.

The standard package for bleach formerly was an enameled-steel drum and for semi-stable compounds glass was used. The shortcomings of these two packs soon became apparent. Glass breakage and corrosion of the drums in hot humid climates were excessive. Therefore, attempts to improve these packages were initiated.

It was necessary to study the entire technique of steel drum manufacture and to make some modifications. Next, the finishing operations were found to be of great importance and, after intensive tests, it was found that lack of enamel adherence would have to be overcome by either a phosphate coating or sandblasting prior to finishing. The enamel coating was next studied and a wide variety of corrosion-resistant highbake enamels were tried. A list of approved phenolic- and vinyl-based enamels that showed satisfactory resistance to bleach was compiled. Drums fabricated according to these results gave a very satisfactory product for use with inorganic chlorinated compounds.

Repeated tests with organic chlorine-containing compounds under tropical storage conditions showed these enameled steel drums had too short a life.

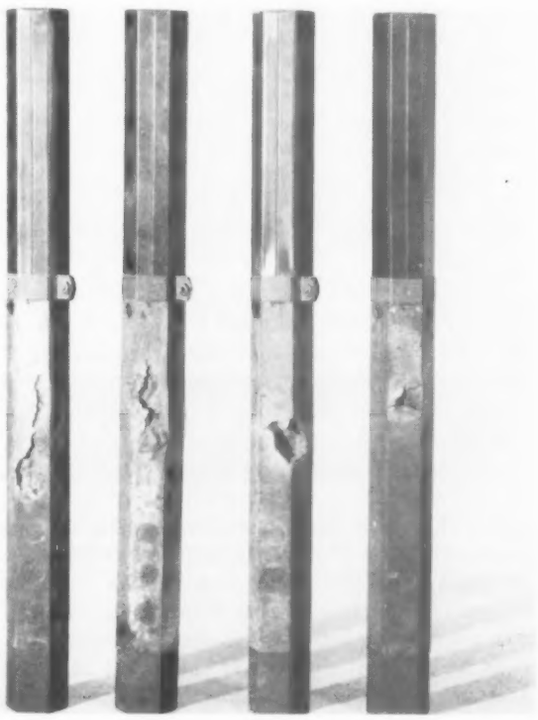
In view of this situation, it was necessary to make a new start. Effort was directed toward the development of fiber, wood, and paper containers. Textile containers, paper sacks, and most plastic bags failed rapidly. Wood barrels and drums had the desired resistance but were excessively heavy and costly when constructed to be sufficiently strong and waterproof. Those plastic bags that showed no degradation were moisture-sensitive or permitted migration of the chlorinated compounds. The only container showing real promise was the convolutely wound fiber drum with fiber head and bottom.

The resistance of these drums to semi-stable chlorinated compounds was excellent and under normal storage conditions was quite satisfactorily. The strength of these drums was seriously impaired, however, when placed in open storage or on wet ground.

To overcome this difficulty, the drums were moisture-proofed by adding an asphalt-laminated outer layer and by coating inside and out with chlorine- and acid-resistant compositions. Surprisingly, all drums tested rapidly failed, probably because the concentration of chlorine and

M-50 MAGNESIUM INCENDIARY BOMBS

An unusual type of corrosion caused by impurities contained in the magnesium castings



acid vapors built up above a critical value so that the cellulose fibers were vigorously attacked.

The idea of coating the inside of these drums with a paint film containing an active material to react with the chlorine and acid vapors was proposed. It was thought that this would keep the corrosive vapor combination below the critical point. Drums internally coated with zinc oxide filled lacquers gave excellent results even when a waterproof coating was added to the outside surface. Such drums have since proved themselves in actual use.

While the development of this fiber drum solved the problem of shipment and storage of solid semi-stable chlorinated compounds alone, we had one steel dual container which was composed of a sealed inner container filled with semi-stable chlorinated compound set above acetylene tetrachloride in the main drum. The use of enameled steel for the inner container was entirely unsatisfactory due to fracture of the coating during closing or subsequent rough handling. None of the coatings tested previously were satisfactory, nor were any of a number of others subsequently tried.

We are now experimenting with molded phenolic and polyester inner containers and the early results are encouraging. We now have a number of them on order and plan to run an extensive test to determine their value under all storage and climatic conditions.

The corrosion of plant equipment presents a number of serious problems. Typical of these is one that, at present, is quite troublesome. In one stage of manufacture, extreme corrosion of equipment occurs at high operating temperatures. The compound that caused the major portion of the corrosion has not been absolutely identified due to the complexity of the reaction.

Ordinary steel equipment is so rapidly corroded that it creates a major safety hazard. The investigation of materials other than steel for use in the construction of equipment has shown that most common metals, except silver, are not satisfactory. The use of silver as a construction material has many disadvantages, two of which are its cost and its low strength.

Various alloys were obtained and tested, but most of the general types, such as stainless steel or monel, showed little advantage over steel. In the Hasteloys, A was disappointing but the B alloy showed only slight corrosion. Pilot plant equipment fabricated from this alloy is standing up quite well, but the cost would be prohibitive on a large-scale operation. Hasteloy C is now under test merely to determine its possible superiority over B.

The use of metal linings is questionable because of the slow corrosion that does take place and the subsequent tear-down and repair that would be necessary. Organic materials, of course, cannot stand the high temperature involved, so it is necessary that we confine our present and future investigations to metals and inorganic materials that will efficiently transfer heat.

Another problem involving extremely corrosive material occurred during the development of a marking device eventually used in tracking V-2 rockets in the upper atmosphere, as reported in detail in the 10 January 1949 "Chemical and Engineering News." The device developed was a smoke generator which was incorporated in the warhead and control chamber of the rocket and consisted essentially of a storage container filled with FS (chlorosulfonic acid-sulfur trioxide mixture), a second storage container filled with water containing a freezing point depressant, a mixing chamber and a delay mechanism by which mixture of the FS and water and the subsequent ejection of the smoke mixture from the rocket through suitable orifices was controlled. By appropriate adjustment of the delay mechanism a smoke cloud clearly discernible at extreme altitudes was formed.

As you probably know, FS is extremely corrosive, and any moving parts are completely inoperable after a few hours exposure to it. Consequently, it was necessary to seal the FS in its container by the use of a quick-opening valve. Any ordinary valve seal material was rapidly corroded before the unit could be put in use, so a search was instituted to find a material which would withstand the acid. A wide variety of leather, natural and synthetic rubber and plastics was tried but none lasted long enough to be of any practical value. Butyl rubber, while better than the rest, still fell far short of the desired resistance. Of the plastics investigated, Teflon (polytetrafluoethylene) showed no deterioration in initial tests. More extensive tests confirmed the first results that Teflon was not affected by FS.

The phenomenal success of Teflon as an inert material has led us to evaluate it and Kel-F (trifluorochlorethylene) for use on other Chemical Corps material with the idea of making use of them when prices become more in line with other materials.

The above corrosion problem involving a smoke-producing agent brings to mind a closely related situation involving the use of FM, which is more commonly known as titanium tetrachloride. This material hydrolyzes in the pressure of moisture, producing hydrochloric acid, and so gives rise to corrosion. Further, the FM itself is an exceptionally good solvent for a wide variety of materials. In spite of these facts, it has been found the most satisfactory agent for use in smoke-spotting charges in conjunction with training munitions. In one case, to facilitate failed filling and to insure an easily fragile container, it was necessary that a glass vial be used and that a simple and positive method of closing this vial be assured. Many materials were investigated as possible "stoppers" for the vial, but it was discovered that most of these materials were either corroded by or slowly dissolved into the agent. As a temporary solution to this problem the selection of Hycar, a synthetic rubber, was made since it appeared to be the least rapidly affected of all sealing materials investigated. However, a plastic or elastic composition completely insoluble in FM and resistant to hydrochloric acid attack could rapidly be used by the Field Forces. This would aid in the fabrication of spotting charges in the field for use with training munitions, with tank mines and the like.

This brief summary of our corrosion problems is naturally incomplete and covers only a limited number of the investigations which we have made in the recent past. At present we are launching a program to evaluate a series of widely diverse organic coatings in regard to their resistance to chlorine, hydrochloric acid, and chlorinated organic compounds. Simultaneously we plan to determine the effect of our various corrosive media on a large number of basic plastic materials, with a view toward the future development of those showing the most promise.

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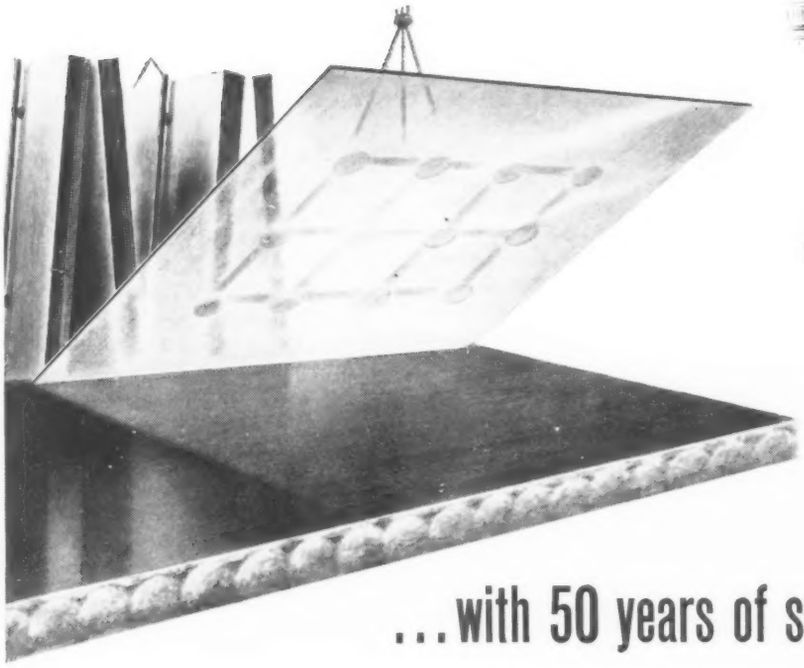

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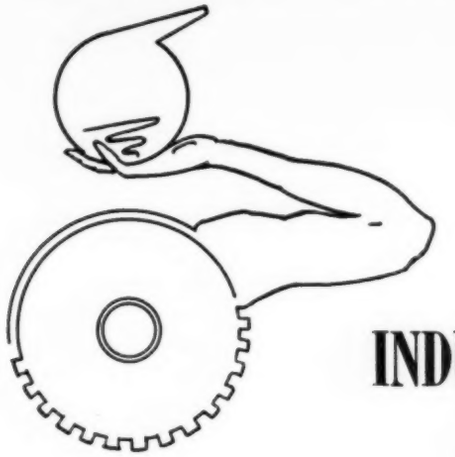

INDUSTRY AND THE CHEMICAL CORPS*

THE CHIEF REPORTS — "BASED LARGELY ON EXPERIENCE GAINED IN WORLD WAR II, POLICIES HAVE BEEN ESTABLISHED TO GOVERN EVERY PHASE OF INDUSTRIAL MOBILIZATION AND PROCUREMENT PLANNING."

By Maj. Gen. Anthony C. McAuliffe
Chief, Chemical Corps

Teamwork between the Army and Industry is the very basis of our security. It establishes a mutual meeting ground between the Chemical Corps and members of the Chemical industry.

I know that all of you are interested in the part which the Chemical Corps plays in the overall National Defense Program for maintaining the security of the United States. World conditions draw particular attention to this highly important phase of our national life.

National security, in its present concept, involves every phase of our existence. It concerns our homes and families, our industry, and our security as a nation. It involves the preservation of our free economic, social and political institutions.

The lessons of World War II clearly demonstrated that the preservation of our way of life required the wholehearted cooperation of industry and the military. The results of industrial efforts in providing Chemical Corps materials, for use on all battlefronts of the world, will pass down to posterity as one of the outstanding achievements of the Chemical industry in the first half of the twentieth century.

I wish to present to you the Chemical Corps' industrial mobilization and procurement planning programs. I shall try to answer questions such as: "What is Industrial Mobilization and Procurement Planning?" — "What is the Chemical Corps' Responsibility?" — 'How Can You Become Part of This Program?"—"What Does the Corps Hope to Accomplish?"

*This article is based on General McAuliffe's presentation to the Louisiana Chapter of the Armed Forces Chemical Association at New Orleans on Army-Industry Day. In the absence of General McAuliffe who was required to be in Washington for Congressional budget hearings, the address was given by Maj. Gen. Floyd L. Parks, Chief of Information, Department of the Army.

Industrial mobilization itself is a program under the jurisdiction of the Munitions Board created by the National Security Act of 1947. The program is primarily concerned with the allocation of private industrial capacity on a priority basis, to all members of the national defense team. Regulations of the Munitions Board, known as Operating Annex No. 47 of the manual entitled, "Allocation of Private Industrial Capacity for Procurement Planning of the Armed Services," govern such allocation.

Many of you are familiar with these documents since they have been given wide distribution by the Munitions Board.

Based largely on experience gained in World War II, comprehensive policies have been established by the board to govern every phase of industrial mobilization and procurement planning. The board hopes to assure the most effective mobilization of the nation's resources in an emergency.

These policies in general govern plans for the military aspects of industrial mobilization and procurement planning among the several military services. Its outstanding features are the standardization of specifications and the allocation of purchase authority of technical equipment and items of common use on the basis of procurement by a single agency.

In other words, the Chemical Corps would be authorized to procure all items of chemical warfare under these regulations and policies. This authority would include procurement for other branches of the Army, the Navy, the Air Force and similar organizations.

Procurement planning is, therefore, an active function of industrial mobilization.

In accordance with the foregoing policies of the Munitions Board, the objectives of the Chemical Corps' Procurement Planning Program become quite clear. Our objective is to prepare, in advance of an emergency, all plans, procedures and activities governing procurement of Chemical Corps material from industry, in accordance with the Corps' mobilization mission and the overall plans of the Department of the Army.

The Chemical Corps, however, has a unique problem in this respect. Over ninety percent of our end items have no commercial counterpart in civilian industry. This means that large-scale conversion of industry would be required to carry out the Corps' mobilization procurement responsibilities. This problem requires comprehensive and detailed planning by the Corps in cooperation with members of the chemical and other industries.

What are some of these problems? They involve the accumulation of technical and production data relative to specific production equipment, and the preparation of manufacturing floor plans, plant layouts and flow sheets. They include assembling operational data on all elements of pro-

duction from the receipt of raw materials to the final packaging of end items.

Such detailed planning, obviously, cannot be achieved without direct contact with industry throughout the United States. This is precisely where technical associations, such as AFCA, render sterling contributions to our overall plans.

The Armed Forces Chemical Association has been a medium through which we contact representatives of the chemical industry. Such contacts permit the dissemination of information and the soliciting of cooperation in further developing our mobilization planning activities. In return, members of the Assocation are familiarized with all activities of the Corps.

Direct liaison and cooperation with industry, however, is the function of the Chemical Corps' six procurement districts. The primary mission of these offices is the execution of industrial mobilization and procurement planning. These functions have been decentralized from our offices in Washington and at Army Chemical Center (formerly Edgewood), Maryland.

The six procurement districts are located in Boston, New York, Atlanta, Chicago, Dallas and San Francisco. They are responsible for all industrial mobilization and procurement planning functions within their respective areas. Although their functions are primarily advisory at the present time, they will become active procurement districts in event of an emergency.

These offices maintain contact with industry on industrial mobilization and procurement planning activities of the Chemical Corps. They collaborate with industrial plant managers in the preparation of production plans for the manufacture of specific items at designated plants. These plans cover the procurement of end items, and of sub-assemblies and other component parts of Chemical Corps materiel for use in our manufacturing arsenals.

The procurement districts also assist in the administration of various types of Chemical Corps contracts. The exploratory study and the educational production contracts are two types of these contracts through which the Corps is helping industry to develop and to maintain production know-how. Conversely, the Corps is also benefitting from these contracts through the recommendations of industry.

I would like to call your attention at this particular point to the fact that it is not necessary to contact any middleman in order to do business with the Chemical Corps.

If any should desire information regarding Chemical Corps procurement within an area, information may be obtained by writing the Commanding Officer of the Chemical Procurement District. The Office of the Chief, Chemical Corps, assigns responsibility for planning the procurement of all end items within the area to respective offices.

For example, at the present time the Dallas Chemical Procurement District is assigned responsibility for the procurement of over 1500 items of industrial reserve equipment on end item schedules. These items include incendiary bombs, decontamination equipment, protective equipment, colored smoke grenades, smoke pots, 105 and 155mm shell cannisters and other types of Chemical Corps materiel.

The Chemical Corps considers the industrial mobilization and procurement planning programs of significant importance to the mobilization readiness plan of the Joint Chiefs of Staff.

Our industrial mobilization and procurement planning estimates for fiscal year 1951, for instance, total $4,492,000, or 11.9% of our total budget.

This sum is considered necessary for maintaining a balanced program in accordance with the four categories of the industrial mobilization plan as designated by the Munitions Board. These categories include: (1) the maintenance of reserve plants; (2) machine tools and production equipment; (3) industrial preparedness measures, and (4) planning within the National Military Establishment in addition to carrying out cataloging and standardization programs.

Machine tools and production equipment held in reserve at the present time by the Corps have an estimated value of $20,000,000. These reserves comprise approximately 10,000 items of special production equipment in addition to 31,000 items of inspection equipment. These items must be preserved in a serviceable condition for immediate use in an emergency. The Corps is, therefore, continuing its program of inspection, verification, preservation for storage and periodic surveillance of these items.

As previously pointed out, a particular problem of the Corps is that over 90% of its items are strictly military in nature and have no civilian counterpart. Many newly developed items have never been produced by industry. Others have never been produced in the quantities required by the mobilization plan of the Joint Chiefs of Staff.

How can this problem be met? The answer seems quite obvious.

We must maintain industrial preparedness contracts with industry to obtain the necessary production know-how. By means of preliminary investigations through pilot plant production, we are able to plan and prepare with industry for future production.

I wish to emphasize that our industrial preparedness measures with industry have already reduced production lead-time of some important items by many months. We hope to reduce this lead-time still further. All of us know how important the solution of these problems are to our mobilization readiness plans.

In this brief survey of our industrial mobilization and procurement planning programs, I have attempted to point out some of its more important phases. It is a continuing problem, however, as you know, to achieve mobilization readiness in time of peace.

But preparedness, of both industry and the military, is a tangible form of insurance which may one day prove to be the deciding factor in maintaining our democratic way of life.

Legislators casting about for new sources of tax revenue seem, strangely enough, to have overlooked a promising proposal once offered to England and the world by Jonathan Swift.

"I propose," said the satirical Swift, "that a tax be levied on female beauty."

"But could we make the women pay enough to make it worth while?" a listener inquired.

"Ah, yes," replied the wily Dean. "Let every woman be permitted to assess her own charms—then she'll be generous enough."

Two little girls were discussing their families.

First: "Why does your grandmother read the Bible so much?"

Second: "I think that she is cramming for her finals."

* * *

Joe was dead and John called on the widow to express sympathy. "Joe and I were mighty close friends; isn't there something I could have to remember him by?"

Tearfully, the widow raised her eyes and whispered softly, "Would I do?"

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EXPERIMENTS

(Continued from page 9)

tional blast operation, periodic reversals of flow have been made to store a maximum amount of heat underground and to stabilize the combustion zone.

Excess oxygen continued to appear in the effluent gases, and it became apparent that a portion of the air blast was contacting hot carbonaceous materials and that large percentages were bypassing the coal faces and flowing through broken rock near and over the center of the original entry. It was decided to inject a fluidized solid medium into the void spaces over the line of the original entry in an effort to force contact between all of the air and the coal faces. Holes were drilled along the line of the entry and sand was fluidized with air and injected into this area. The following table 2 shows the effect of admission of the fluidized sand on the back pressure or resistance to flow through the system.

TABLE 2.—*Back-pressure development*

	Av. back pressure at 7200 c.f.m. air flow pounds per square inch gage
May	4.1
June	5.0 [1]
July	6.9
August	8.2
September	9.4
October	13.1

[1] Admission of fluidized sand was started June 22.

The following, table 3, summarizes operation of the project since its ignition in March, 1949.

TABLE 3.—*Coal consumption and heat balance*

Month	Coal consumed, tons[1]	Cumulative coal consumed, tons[1]	Coal consumed, tons[1] per day[2]	Heat balance, percent of heat of combustion of coal consumed: Sensible heat content of dry effluent gas	Heat of combustion of dry effluent gas	Sensible and latent heat content of moisture accompanying dry effluent gas	Heat stored underground by difference
March, 1949	120	120	8.9	21.3	9.3	—	59.4[3]
April	201	321	6.7	31.9	11.6	—	46.5[3]
May	312	633	10.1	36.0	23.5	—	30.5[3]
June	337	970	11.2	29.7	34.2	—	26.1[3]
July	452	1422	14.6	24.4	24.3	—	41.3[3]
August	441	1863	14.2	22.9	26.2	11.2	39.7
September	485	2348	16.2	19.1	32.0	11.7	37.2
October	583	2931	18.8	21.4	34.1	13.7	30.8
November	454	3385	15.9	17.9	31.9	11.5	38.7
December	535	3920	19.7	18.4	24.2	8.9	48.5
January, 1950	486	4406	15.7	7.7	22.9	12.8	56.6

[1] Basis of moisture-and-ash-free coal.
[2] Total tons divided by operating days.
[3] Assuming 10 percent for heat content of moisture.

During the period from March through September, it will be noted that the rate of combustion of coal was virtually doubled. This increase of combustion rate was largely due to the use of the fluidized sand. It indicates the degree of success attained in blocking off underground crevices and void spaces by the use of this technique.

In October, November, and the early part of December, the length of time between reversals of flow was increased, and it was found that a combustible gas was being generated on the coal faces and subsequently burned by bypassing oxygen underground. During this period, the 20-inch outlet stacks were operated at temperatures of 1,600° to 2,400° F. with gas burning in and above the stack. During this period coal consumption near the base of the outlet stack increased and the gaseous products were

evolved at temperatures high enough to make possible their use in raising steam or in operating a gas turbine. The heat balances run on the operation show that more than 50 percent of the heat of combustion of the coal is brought above ground in the effluent gases.

Samples of gas were taken from test holes estimated to be very close to the burning coal faces, and typical analyses are shown in the following table 4:

TABLE 4.—*Analysis of gas flowing near burning coal ribs*

Sample point	Test hole 6[1]	Test hole 13[2]
Gas analysis		
CO_2 ..... percent	10.4	8.5
III ..... do.	.3	.2
O_2 ..... do.	.7	.0
H_2 ..... do.	10.9	11.4
CO ..... do.	10.0	15.5
CH_4 ..... do.	2.3	2.0
N_2 ..... do.	65.4	62.4
Heating value..B.t.u. per cu ft.	97	111

[1] Sample point 75 feet north and 35 feet east of outlet stack, direction of blast north to south (II to I).

[2] Sample point 30 feet west of outlet stack, direction of blast south to north (I to II).

Effluent gases having the following composition were obtained just prior to ignition of the gas by bypassing air underground. It is apparent that a large volume of excess oxygen is still present.

	Average percent
CO_2	8.8
III	.3
O_2	10.0
H_2	2.6
CO	2.0
CH_4	.8
N_2	75.5
Heating value, B.t.u. per cu. ft.	29

One of the objectives of this underground gasification experimentation was to determine the quantity of coal that could be burned from a given initial combustion zone. In table 3 it is shown that 4,406 tons of coal were burned between bore holes I and II from March 1949 through January 1950. This data and information obtained from the test holes indicate that the coal faces have receded by 40 feet midway between bore holes I and II and by 65 feet near the bore holes themselves. This means that a total area approximately 130 feet wide at the bore hole, 80 feet wide at the midpoint of the passage, and 400 feet long has been burned out, and to date no limit as to the quantity of coal which can be utilized from a given initial passage has been reached.

From the beginning of the operation of the project to date, it has not yet been possible to determine the optimum length of path underground. Experimentation at this time is being carried on to determine the effect of a shorter-length path or combustion zone by means of the construction of bore holes off the line of the original entry at appropriate locations. One such trial hole has already been installed and tested, and using a combustion zone having a length of 150 feet, it was possible to produce a gas having a heating value of 90 B.t.u. per cubic foot for an 8-hour period. Other experimental work now being carried out is being directed toward concentrating the combustion zone in a specific location and also to controlling bypassing of the blast medium, air, by plugging underground crevices and openings through the use of fluidized, finely divided solid mediums.

When investigation of underground gasification processes was begun, it was felt that the development and construction of such types of installations would cause serious difficulties. To date, the experimental installations at Gorgas have proved quite adequate to maintain and exercise a measure of control over the combustion of coal as it is naturally situated underground.

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AIRPLANE SPRAY

(Continued from page 15)

was flush with the bottom and carefully faired into the contour of the tank. The air inlet vent was located on the top of the tank as in the E9R4 tank, and both vent and discharge were equipped with frangible glass closures. Perforated baffle plates were built into the tank to prevent surge of the liquid contents. The narrow space between the top of the tank and the under surface of the wing was enclosed by a streamlined fairing. Four of these tanks with fairings were constructed, but since no A-20A airplane for which they were designed was scheduled to come off the production line for some time, tests were never conducted.

The M10 Spray Tank

The E12 spray tank, subsequently standardized as the M10, is a streamlined body of revolution based on the NACA 0.07-020 airfoil section. The horizontal discharge pipe is streamlined into the lower portion of the tank and the conventional air inlet vent is secured in position in the top forward portion of the tank. When the air inlet elbow is removed, the opening provides a hole for filling the tank. The tank is suspended from the conventional external bomb racks of aircraft and is provided with two hoisting lugs for raising the tank into position. The tank is reinforced at each lug position by a small steel plate welded inside the tank. When the M10 tanks were installed on the A-20A airplane, the space between the wing and each tank was enclosed by a streamlined fairing, which covered the rack completely. These streamlined fairings decreased the air resistance of the installation and gave more positive control of the airplane by partially eliminating the burbling of the air near the ailerons. All fairings were identical and could be used on the right or the left wing installations. The air inlet elbow of the M10 tank was provided with an offset nozzle which could be pivoted to permit the necessary adjustment. Because of the difficulty of, and the time required for, installation of fairings and the necessity of providing different fairings for each airplane installation, their use was abandoned. The streamlining of the bomb racks was improved, their location lowered, and the spacing of adjacent tanks increased on subsequent airplanes in an effort to decrease some of the adverse effects resulting from the elimination of the fairings. Each tank had a gross capacity of 33 gallons and discharged its contents of about 30 gallons at speeds of about 275 miles per hour in the average time of 6 seconds for the various chemical fillings. The tank proper was approximately 14 inches in diameter at its midsection and 68 inches in length. The over-all height of the tank, including the provision for the discharge line was about 20½ inches. Following the principles employed with the E9R4 tank, closure plates with detonators were provided to seal both the discharge and vent openings. The weight of the empty tank, which was constructed of copper bearing steel, was 68 lbs.; the weight of the fairing, when used, being 11 lbs. A later revision of this tank permitted its carriage from either single or double lug suspension bomb racks.

The M33 Spray Tanks

Up until the end of 1941 emphasis on airplane spray tank development had been placed on wing tank installations, although a bomb-bay installation with an electrically operated retractable discharge line was designed for the A-20A airplane but was never constructed. Shortly after our entry into World War II, it became apparent that, in order to be prepared for successful retaliation in the event that the enemy should initiate large-scale chemical warfare, it would be necessary to provide all of our Army bombers with spray tanks from which they could rain war gases upon the enemy in unlimited quantities. A project was initiated for the development of bomb-bay spray tanks for medium and heavy bombers since, in general, such airplanes were not provided with external wing racks from which wing spray tanks of the M10 type could be suspended. The B-25 airplane was selected as the first airplane in which bomb-bay chemical tanks were to be installed.

It was desired to develop a tank having the maximum possible capacity. The first tank developed and successfully flown in this airplane was a cylindrical tank, 24⅞ inches in diameter and 83¼ inches in length, with dished heads. Installational difficulties were encountered when tanks of this design were installed in the B-17 airplane. A number of modifications were made to the tank in an effort to retain the maximum possible capacity for use in the B-25, B-26, B-17, and B-24 airplanes. So much difficulty in accomplishing this was encountered that it was decided to limit the external contour of the tank to approximately that of the 2000-lb. bomb, since these airplanes, as well as other medium and heavy bombers on the drawing board, were designed to carry this bomb. This necessitated a considerable sacrifice in capacity. The first tank developed for the B-25 airplane had a capacity of approximately 230 gallons while the M33 tank, which had the same general contour as the 2000-lb. bomb, had a capacity of only 78 gallons. In order to protect the contents of spray tanks carried in long-range bombers from freezing, provisions were made to use insulating covers on these tanks when needed.

The M33 tank consisted of a container, a closure plate assembly, a discharge line assembly, and other parts required for its proper functioning. The container was a symmetrical cylindrical tank with ogival ends made of 16-gauge copper-bearing steel. It had an outside diameter of 21⅜ inches and an over-all length of 64¾ inches without its insulating cover. With this cover or jacket in place, no part of the tank except the discharge flange and discharge pipe extended beyond the limits of the body of the 2000-lb. bomb. The tank was suspended from the 2000-lb. bomb station. The insulated tank was 23⅛ inches in diameter and 66½ inches long.

The empty tank, provided with the discharge line for use on the B-25 airplane, weighed approximately 200 lbs., and had a fillable capacity of 70 gallons. The suspension lugs were similar to those of the bomb and were secured to a pair of circular bands which encircle the tank. These bands could be rotated to permit the installation of the spray tank in the different airplanes. The circular bands were connected by two 5-inch width pads against which the sway braces of the various airplanes bear.

The closure plate assembly consisted of a flange containing one large and one small circular opening. Concentric with the latter, a standpipe was welded and this projected inside and to within about an inch of the top of the tank. The top of the standpipe and the discharge opening at the flange were closed by two closure plates and the assembly was bolted to the closure flange of the container. One- or two-piece rigid discharge lines were required for satisfactory installation of the tank in the various airplanes.

During the course of this development, a number of very complicated retractable discharge lines were tested but were found unnecessary since the rigid lines gave adequate ground clearance with very little if any contamination of the airplane. The discharge line was secured to the tank by means of a two-piece clamp and consisted of two sections. The forward section permitted

the entrance of air at the leading edge and directed it upward through the standpipe into the tanks. The rear portion directed the discharging liquid downward and to the rear.

Prior to the installation of the tank on the airplane, it was provided with a blind flange instead of the discharge line. This flange acted as a protection for the discharge closure plate and prevented any leakage of the tank in the event that leakage at the closure plates occurred.

Shattering of the plastic or dished pyrex closure plates by the firing of electric detonators caused the tank to function. Air entering the air inlet opening of the discharge line was directed upward through the closure plate assembly standpipe to the top of the tank, creating a positive pressure which facilitates the discharge of the contents of the tank. The liquid contents passed down through the discharge line and were ejected to the rear.

The center of gravity of the tank filled and ready for hoisting in the airplane was 1 inch or less, depending upon the filling used, to the rear of suspension lug center line. With the discharge line in place, the center of gravity was slightly farther to the rear. The center of gravity of the empty tank was approximately 5½ inches to the rear of the center line.

The air inlet opening of the discharge line may be covered with an ice shield to prevent the entrance of freezing water into the air inlet of the discharge line. Ice, however, may form on the outside of the shield. At the moment of functioning of the tank, the ice shield can be blown out by the action of an electric detonator, taking with it any ice which may have formed on the outside of the air inlet opening.

The M33A1 Spray Tank

As the total weight of a filled M33 tank was only about 1,100 lbs., and since most fighter airplanes were capable of carrying 1000-lb. bombs, consideration was given to the possibility of carrying these tanks from the wing stations of fighter airplanes. A discharge line with a minimum vertical height was constructed and new suspension bands and lugs to permit the carriage of this tank from 1000-lb. bomb racks were improvised. Tests of this equipment suspended from the bomb racks of various fighter airplanes disclosed the feasibility of its use on external wing racks. Although it was realized that this tank did not possess the streamlined characteristics desired for externally mounted tanks, a decision was made to so modify the M33 tank as to permit its use from external 1000-lb. bomb racks as well as 2000-lb. bomb racks. The M33A1 tank, as this new tank was designated, is shown in Figure 7. It incorporated a stronger and improved container, universal suspension bands adjustable for use on 1000-lb. or 2000-lb. bomb racks, and the short discharge line shown, in addition to the discharge lines provided with the M33 tank.

The M40 Spray Tank

External bomb racks were being installed on the B-17 and B-24 airplanes to increase the load-carrying capacity of these airplanes and it was considered desirable to make provisions for the carrying of chemical tanks on these new racks. Preliminary flights of the B-29 airplane capable of carrying 4000-lb. bombs were being made at this time so that it was logical to develop the new tank for use in the bomb bay of the B-29 airplane as well as on the external wing racks of the B-17 and B-24. Recalling the difficulty encountered in the development of a high-capacity tank (the predecessor of the M33 tank) for use on medium and heavy bombers, the contours of the 4000-lb. tank were followed and as many of the parts and features of the M33A1 as possible were used in the development of the 216-gallon M40 tank, which was the "big brother" of the M33A1 tank. Tests of the M40 tank carried on the B-17 and B-24 airplanes proved that the tank would function satisfactorily on these airplanes. No tests of the tanks installed in the B-29 airplane were ever conducted because the use of such large airplanes for releasing chemical agents at low altitudes was not considered tactically feasible.

Tanks for Spraying Insecticides

Our troops were fighting in all parts of the world and it became necessary not only to battle the enemy but to fight disease as well. Early consideration was given to the possibility of using aerial spray of DDT and other insecticides to combat insects in inaccessible areas. Several different types of insecticide spray equipment were developed. M10 and M33A1 tanks, sometimes with modifications of the discharge lines to decrease the rate of discharge and the size of the spray particles produced, had been employed but later were supplanted by equipment especially developed for this purpose. Only one tank, which is very similar in general characteristics to the other tanks considered in this paper but having a much lower rate of discharge, will be described here. The E20 tank (Figure 8) was a 165-gallon jettisonable fuel tank modified by the addition of a 1½-inch air inlet elbow attached to the filling opening and the substitution of a 1¼-inch solenoid-operated valve for the strainer plug at the bottom of the tank. A vertical discharge pipe was attached to the valve. The discharge from this type of discharge pipe is subjected to greater shearing action of the air and results in smaller particle sizes than that obtained with the conventional discharge pipe. This tank can be carried on high speed fighter airplanes and has been found to function very satisfactorily. The dynamic air pressure obtained on the inside of the tank by the use of the air inlet elbow helps to keep the discharge pressure constant and the rate of discharge uniform. Considerable difficulty was experienced in maintaining a uniform rate of discharge in some of the DDT spray equipment developed which did not make use of dynamic air pressurizing of the container. No attempt will be made in this paper to describe any of the other types of aerial insecticide sprayers which have been developed.

Conclusion

The author has attempted to describe very briefly, and with the omission of reference to spray apparatus not directly concerned with this development, the evolution of those airplane spray tanks which were available in very large quantities for use against the enemy during the war, had the enemy decided to use toxic gas against us. In preparation for this eventuality, practically every Army and Navy airplane had been tested for the satisfactory release of full loads of chemical agents from standard airplane spray tanks. Difficulties encountered in making these installations and in overcoming them are not touched here. Only a limited number of these tanks were used during World War II in the smoke screening of some of our landing operations, the protection of our installations, and in confusing the enemy. M10 and M33A1 tanks installed on and being used for the release of simulated agents from the P-47 airplane are shown in Figure 9. The development of airplane spray tanks in the past has paralleled in many respects the development of the airplane. The rapid strides being made at the present time in the development of new aircraft would indicate that considerable difficulty may be encountered in adapting our present standard tanks or in developing new tanks for use on such aircraft.

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AFCA PHOTO REPORT

FOR SERVICES RENDERED—Col. L. Wilson Greene, CmlC-Res., (third from right), past president of the Army Chemical Center Chapter, AFCA, receives a plaque from Dr. Seymour D. Silver, chapter president.

The plaque was awarded to Colonel Greene in recognition of his services to the chapter. The presentation was made recently at Technical Command where Colonel Greene is scientific director. Dr. Silver is chief of the Bio-analytical Branch of Medical Divison, Army Chemical Center.

Technical Command personnel witnessing the presentation were (left to right) Brooks Smith, assistant chief, Test Division; Dr. Fred W. Lane, research associate; Bruce Hildebrand, assistant to chief, Plants Division; H. V. Wright, chief, Plants Division; Louis Benjamin, chief, Test Division; and Major Floyd B. Mitman, executive officer, Technical Command.

Colonel Greene serves as Associate Editor of The Armed Forces CHEMICAL JOURNAL.

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ARMY REORGANIZATION

With Army Secretary Gray, Chief of Staff Collins and other representatives of the Department of the Army as principal witnesses, a House Armed Services subcommittee began hearings last month on the long-pending Army reorganization bill.

The involved bill sent to the House and Senate last July prescribes a general organization plan for the Army, its general staff and its branches.

Instead of the detailed organization spelled out in the National Defense Act and other laws, and now largely superseded by reorganizations under wartime authority, a permanent organization is set up in general terms, giving the Army Secretary power to meet changing conditions.

The wartime Transportation and Military Police Corps are made permanent, the Field and Coast Artilleries are combined into an Artillery branch, and an Armor branch replaces Cavalry.

But the bill, while spelling out these so-called "basic branches" gives authority for additions, consolidations or abolitions as circumstances require.

However, the bill would have to be amended to change any of the "special branches" it names—the various corps of the Army Medical Service, the Judge Advocate Generals Corps and the Chaplains.

The change in name of the Army Medical Department to Army Medical Service, and the renaming of the Adjutant Generals Department, Finance Department and Ordnance Department as Adjutant Generals Corps, Finance Corps and Ordnance Corps will reserve "department" as a top-level designation.

The historic term "Army of the United States" would become "United States Army" although the bill otherwise does not affect any of the civilian components of the so-called Section 5 General Staff Policy Committee.

Nothing in the bill authorizes federalization of the National Guard, assured Secretary Gray who once headed a committee which recommended that move.

In reference to the Chemical Corps, the bill would authorize a "Chief Chemical Officer" for the Department of the Army.

IT COST A MILLION

The delay in issuing the Executive Order designating the agency responsible for payment, hospitalization and reexamination of military personnel retired for physical disability is costing the government $1,000,000 a month.

At present there is an accumulated backlog of 3,000 officers and enlisted men who have qualified for retirement on account of disability, but who continue to draw active pay while awaiting the designation of the agency responsible for their retirement payments. The difference between active and retired pay of these persons is $1,000,000.

This information was brought out in testimony of Maj. Gen. Raymond W. Bliss, Army Surgeon General, before a subcommittee of the House Armed Services Committee. There have been no retirements of Reserve officers and enlisted men for physical disability since last September.

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BRANCHES IN PRINCIPAL CITIES

ANTIBIOTICS AND PFIZER & COMPANY*

"IT IS PARTICULARLY FITTING ON THE COMPLETION OF PFIZER'S FIRST CENTURY OF OPERATION THAT THE COMPANY FINDS ITSELF A PIONEER IN ONE IMPORTANT ASPECT OF THIS NEW WORLD; IN THE DISCOVERY, DEVELOPMENT AND MANUFACTURE OF ANTIBIOTICS."

By John E. McKeen, President
Charles Pfizer and Company

In 1849, two young German immigrants by the name of Charles Pfizer and Charles Erhart founded the company bearing the former's name in a small brick building at the corner of Bartlett Street and Harrison Avenue in Brooklyn. This, you will recall, was the same year that James Marshall discovered gold in Sutter's Creek, California.

From the above date through the first four decades of the 20th century, civilization has probably made greater material advances than in the preceding 1,000 years. However, within the *last decade* a completely new frontier has been opened—the world of the infinitely small; the world of the atom, the neutron, the meson, the antibiotic and the virus. These developments, in my opinion, will shortly make the railroads, bridges, tall buildings, and airplanes symbols of past conquest of man over nature.

The Last 100 Years

It is particularly fitting on the completion of Pfizer's first century of operation that the company finds itself a pioneer in one important aspect of this new world; in the discovery, development and manufacture of antibiotics. Nevertheless, the role of pioneer in the drug industry can hardly be regarded as a new experience to the Pfizer organization. The company's pioneering activities in the drug industry actually began in 1849 with the manufacture of a new pharmaceutical item, Santonin, a vermifuge, containing the active derivative of wormseed. Shortly, thereafter, the company expanded its activities to the manufacture of the important iodide preparations including potassium iodide, iodine resublimed and idoform. By 1855, Pfizer was producing other significant drug items such a calomel, boric acid and refined camphor.

Pfizer pioneered in 1862 in the production of tartaric acid and cream of tartar—both important items in the current Pfizer line.

The manufacture of citric acid, now one of Pfizer's most important non-pharmaceutical products, was undertaken in 1880 from lemon and lime concentrates. This again was a pioneer venture.

The next milestone in Pfizer's history was the first successful commercial synthesis of citric acid. Faced with the problem of obtaining a constant supply of citrate of lime at reasonable prices, Pfizer in 1914 set up a special research program on the fermentation of citric acid from a sucrose base. On the basis of this research, pilot plant operations were begun in 1919. Full-scale plant facilities were established in 1923.

A number of major refinements in processes and increases in production facilities have subsequently been made in citric acid. Some indication of the progress made may be obtained from the fact that from $1.25 per pound in World War I, the price was reduced to $0.20 per pound by 1939. The $0.20 price remained throughout World War II; despite major increases in raw material, labor and operating overhead, a fact in which the Pfizer management takes consideral pride.

The versatility of the fermentation processes is evidenced by the first commercial production of gluconic acid in 1929. Itaconic and fumaric acid were later developed using the same basic fermentation processes.

By combining organic synthesis with the basic fermentation processes, Pfizer in 1936 became one of the first companies to perfect the synthesis of Vitamin C.

A major consolidation and expansion of Pfizer production occurred between 1937 and 1942 when over $3,500,000 was spent for plant modernization of citric and gluconic acid facilities, the erection of new research laboratories and the construction of a new plant for ascorbic acid and riboflavin production. Thus, by 1941, Pfizer products could be classified according to productive techniques into four groups:

1. The inorganic chemicals includ the mercurials, iodides, bismuth preparations, etc.;
2. The synthetic chemicals such as riboflavin;
3. The fermentation or biochemical products—citric acid, oxalic acid and gluconic acid; and
4. Those products which are the result of a combination of synthetic, organic and fermentation processes; for example, Vitamin C (Ascorbic Acid).

In December 1941, at a joint meeting with government officials in Washington and British scientists, together with representatives of four of America's leading chemical and pharmaceutical houses, Pfizer and two of these companies agreed to work on the problem of developing a large-scale production of penicillin.

You may recollect that it was decided initially to concentrate on the flask process; a method quite unsuited to large-scale production. Pfizer also began to work concurrently on a mass-production, low-cost process for the manufacture of penicillin. By late fall of 1941 Pfizer, drawing on its 20 years of deep-tank fermentation experience, not only had a new process in operation but also had placed test products in the hands of the medical profession. Early in 1942 initial deliveries of penicillin manufactured by this process were made to the U. S. government. How this new process completely revolutionized the manufacture of penicillin; thereby saving many thousands of lives, is now a well-known story, requiring little further elaboration.

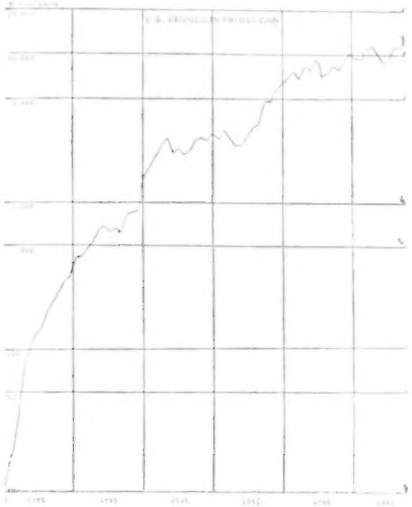
The Outlook for Penicillin

One of the subjects presented me for discussion is the question of "just how low the price of penicillin can go and still remain a profitable pharmaceutical item." In an industry where a change in mold type or production techniques can easily increase productivity from 20 to 50% virtually overnight, this, you will appreciate, is a very difficult if not impossible question for any producer to answer. However, I will do the best I can

*This article is based upon the address of Mr. McKeen to the New York Society of Security Analysts.

to give you some indication of my thinking on this problem.

The succession of major price declines that have occurred in the penicillin industry are graphically illustrated in the accompanying chart.



It is our opinion that the factory price level (not to be confused with the consumer price level) on penicillin in the parenteral form has now reached the point where further price decreases by the manufacturer on all but a few specialty items will have little or no appreciable effect on the consumer demand. Oral penicillin, on the other hand, is still a relatively expensive pharmaceutical item; consequently factory price reductions in this field conceivably may still have some bearing on consumer demand.

But first let me review briefly the background of the penicillin industry. Back in 1942 and 1943 the government, appreciating the critical need for a superior anti-infective, made many exceedingly attractive concessions to the penicillin industry; such as government-financed facilities, special priorities, etc. As a result of this situation many pharmaceutical companies lacking the basic production know-how were drawn into the antibiotic market. Operating in a sellers' market up to 1948 even the less efficient of these artificially subsidized producers understandably had little difficulty in developing and expanding their operations. However, by late 1948 these producers began to feel the effect of the almost forgotten hard-boiled law of supply and demand. The royal road to success in the antibiotic industry had come to an abrupt and rocky ending.

Seeking some way out of this supply-demand dilemma, many of the producers attempted the introduction of a wide variety of penicillin specialty forms and dosages. A few of the larger pharmaceutical houses enjoyed some limited success in such ventures. Others, lacking the extensive distribution setups of the larger houses, resorted to distress merchandising. While a portion of this excess productive capacity has since been absorbed by the subsequent growth in demand for penicillin, many producers are still operating at a fraction of their plant capacities.

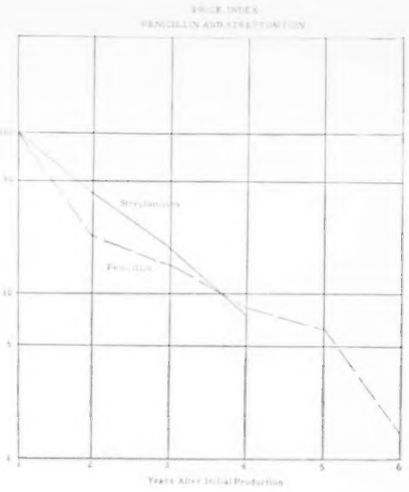
Outlook for Streptomycin

The situation with reference to streptomycin differs in certain respects from penicillin, although in other regards it is closely analogous.

Because of the specialized indications for the product and since the product was not introduced until after the termination of actual hostilities the government did not attempt to subsidize or support its production. Thus the majority of the penicillin manufacturers, already heavily committed to the production of penicillin, were quite content to adopt a wait-and-see attitude. Consequently, streptomycin did not experience the exceptional growth rate of penicillin. This is evidenced by the preceding chart comparing the rates of growth of penicillin and streptomycin beginning one year from their introduction.

Nonetheless, price competition on streptomycin as indicated in the following chart was virtually as intensive as on penicillin. This may be explained by the fact that while there were somewhat fewer producers, the product in comparison to penicillin had a very limited market.

With domestic streptomycin production easily 200 to 300% in excess of domestic consumption, the key to the streptomycin picture is clearly the foreign demand for this product. With the establishment of foreign manufacturing facilities now underway in several major foreign countries, it is not inconceivable that



streptomycin exports will decline from 40 to 50% during the next twelve months. It is difficult to see how this can materialize without major effects on the existing streptomycin price structure.

Taking into consideration prevailing circumstances with reference to penicillin and streptomycin, it is quite apparent that further price reductions are highly probable on both products. Assuming even the most favorable set of circumstances, namely that demand were to equal full productive capacity, it is quite apparent that the prevailing price structure allows only nominal profits in comparison with 1946 and 1947 levels. Thus penicillin and streptomycin have changed from high-margin pharmaceutical specialties to mass produced low-profit pharmaceutical staples.

Where Does Pfizer Stand?

The question remains as to which category Pfizer will fit in this high competitive market. Of course, it is only natural for a person to think his company will come out on top. I am no exception. My reasoning follows these lines. Call it wishful thinking if you will. Both penicillin and streptomycin are manufactured by aerobic fermentation. Pfizer's experience with this type of operation dates back to 1919 with the first manufacture of citric acid by deep-tank fermentation. Pfizer today is probably one of the world's largest producers of aerobic fermentation products, according to information appearing in the magazine *Chemical Industries*.

Thus, as the world's largest manufacturer of aerobic fermentation products Pfizer is believed to be particularly well-suited to the aforementioned type of manufacture.

New Products—Key to the Antibiotic Industry

From the preceding analysis it is apparent that neither penicillin nor streptomycin furnishes any real in-

dication of the outlook for the antibiotic industry. From a profit point of view, and that is what I believe you gentlemen are primarily interested in, the only realistic solution to this problem lies in the development of new and exclusive antibiotic specialties. This as I have previously indicated is an exceedingly costly and vigorous alternative; nonetheless, it is the avenue of approach being most extensively explored by certain leading antibiotic houses today. This is the approach being followed by Pfizer.

New products, of course, presume research. During the last two years, Pfizer has more than doubled research facilities and personnel. These activities fall principally into four categories; biochemical, organic chemical, chemical engineering and medicinal or clinical research. Biochemical activities include the maintenance of a culture screening program, medicinal bacteriology, pharmacology, biochemical engineering, and the study of atomic isotopes in fermentation. The organic chemical research program undertakes the synthesis of organic products, molecular structure studies, application of physics and instrumentation and applied pharmaceutical research. The chemical engineering branch of Pfizer's research activities handles process development, equipment design, plant layout and pilot plant operation. In the latter connection, within the last year a large fully-equipped building has been constructed for chemical engineering and process research. Pfizer also conducts its own engineering research on a processing equipment.

The most recent and probably most important research discovery by Pfizer is the new antibiotic, Terramycin. While the development of penicillin took 13 years from its inception to commercial production, Pfizer, utilizing newly-developed production line techniques, discovered, isolated, crystallized and developed appropriate techniques for manufacturing Terramycin in less than 12 months. Terramycin is now undergoing what is belived to be the most extensive clinical trials ever undertaken by a single company on an autibiotic product. This product has certain important advantages. It may be administered orally. It is characterized by the relative absence of side effects. Our clinicians report that the product has an exceptionally broad spectrum including the possibility that it may have unique value in the treatment of influenza and certain other infectious diseases not yet covered by existing antibiotics. Thus Terramycin may well be the most significant antibiotic discovery since the discovery of penicillin.

In addition to Terramycin, Pfizer's various research activities have played an important role in the development of the Vitamin A synthesis, of Vitamin B_{12} concentrates, the synthesis of caffeine and theophylline and Bi-Con APF, an animal feed supplement.

Diversification

In common with most houses that participated in the wartime manufacture of penicillin, Pfizer found itself in the post-war period with an exceptionally high percentage of sales in antibiotics.

It will be appreciated that during and immediately following the war, it was necessary to concentrate all efforts on making antibiotics available in sufficient quantities to meet military and civilian requirements. It was these efforts that unquestionably saved many thousands of lives. Thus, Pfizer found itself in the post-war period with an exceptionally high percentage of sales in antibiotics.

Management, quite aware of the profound changes that had occurred in the Pfizer operation during the war years, undertook in 1948 a thorough revaluation of the problems confronting the company. One of the principal objectives of this study was to develop ways and means of broadening the sales base. Among the important results obtained was the aforementioned re-emphasis of the research function. Nevertheless, of equal importance was the integration of the sales operation into Pharmaceutical; Feed-Food and Beverage; and, the Industrial Chemical Sales Division; each with its own staff, functions and responsibilities. At the present time, approximately 45% of Pfizer's total sales are in antibiotics with the balance fairly evenly divided between the medicinal chemical, industrial chemical and food, feed and beverage classifications.

Diversification has been adopted as a guiding principle of company operations not only in sales but in the establishment of plant and manufacturing facilities. In addition to the original plant at Brooklyn, Pfizer has a plant at Groton, Connecticut; a plant at Terre Haute, Indiana; and a plant at Maywood, New Jersey. One important characteristic of this multi-plant operation is the fact that many of the company's products can be made at any one of the three larger plants, dependent upon the availability of raw materials, shipping facilities and location of markets. This arrangement contributes materially to the diversity and flexibility of the overall operation.

Conclusion

I have attempted to provide some indication of the outlook for penicillin and streptomycin as well as the antibiotic industry in general. In addition, in the briefest possible manner the history of Chas. Pfizer & Co., Inc., has been reviewed, its product line and the roles it has played in the development of the chemical, medicinal-chemical and antibiotic industries. In this period of rapid change in the chemical and pharmaceutical industries, it is perhaps unwise to make any statements regarding the future. Despite this caveat, I will still venture to predict that our new research-production-sales team during the next 10 years will come up with developments that may dwarf even our previous wartime experiences.

ATTENTION, AFCA MEMBERSHIP

Since the Association is in the process of preparing the new Membership Directory, it is requested that all desired changes in spelling of name, rank and address be forwarded National Headquarters, 1129 Vermont Ave., N.W., AT ONCE.

CIVIL DEFENSE

(Continued from page 5)

fense forces to prevent or counter air attacks upon this Nation; and second, it provides a basis for initiating air raid warnings to civil defense officials and to the general public. The personnel requirements of an observer and filter system are numerically and economically beyond the capabilities of our military organization and dictate the establishment of such a service as a civilian volunteer organization. This is in consonance with the traditions and practices of this country to place major dependence upon its civilian army in the event of war and even greater dependence on wholehearted volunteer civilian participation in activities supporting the military effort.

The formation and establishment of an aircraft observer system after a war emergency has been forced upon us is entirely impracticable. Its chief value is in its readiness to operate at any time. Although the training of individuals who will participate in this activity is neither arduous nor particularly time-consuming, the development and establishment of a completely organized and well-trained corps requires many months of progressive effort. It has, therefore, been decided to organize this observer system now, to establish the observation posts and filter centers, to train the personnel and then place them in a stand-by status.

Observer System a Reality

The plan for the establishment of an aircraft observer system across the United States is not merely a paper plan. It has been thoroughly "war-gamed" and tried in a full-scale operation. Observation posts and filter centers were established throughout the greater portion of ten northeastern states last summer; personnel was recruited and trained and a civil air raid warning system was installed. The entire installation was tested last September in a ten-day exercise conducted by the United States Air Force and known as "Operation Lookout." This exercise proved the efficacy of a civilian observer system; it proved the feasibility of creating such a system through volunteer participation, and it proved the practicability of utilizing existing communications media in an integrated civil air raid warning system. As a result of "Operation Lookout" there is now established in parts of ten states in our northeast area a stand-by organization and there has been evolved a tried and tested plan for the installation of an Aircraft Warning Service incorporating observation posts, filter centers and warning system which will effectively assist in the air defense of the United States and give maximum warning to its citizens and civil defense forces in the event of an emergency.

The current phase of the Aircraft Warning Service program includes the completion of the installation in those "Lookout" states which were partially organized for the original test and the expansion of this service in fifteen additional states in the northeast, Great Lakes and West Coast areas. It involves the establishment of approximately 8,000 observation posts and 26 filter centers. To man these activities upwards of 160,000 civilian volunteers will be required. Adhering to sound principles of following established channels of civil government, the governors of the states involved have been requested to assist in the implementation of the program by assigning to their civil defense or other specially created headquarters the responsibility for recruiting and administering the organization within their respective states. The training and operational control will be the responsibility of the United States Air Force.

Observation posts will be located in cities and towns at intervals of approximately eight miles. The United States Air Force designates the towns according to a pattern of desired coverage. The states are requested to name a supervisor for each location and the supervisor is to assume the responsibility for locating the post where the various requirements of visibility, communications and accessibility can be satisfied. Existing telephone facilities will be used for observer reports; aside from priority service given to "flash" calls from the subscriber phone at the designated observation post, no special telephone facilities will be provided. The post supervisor will be responsible for recruiting and maintaining an organization sufficient in number to man the post continuously in an emergency. Filter centers will be installed by the United States Air Force at designated places. Filter center operations will be recruited under the direction of the state headquarters, and volunteers for this service will be trained at the centers by cadres of Air Force personnel. Special air raid warning telephones will be installed by the Air Force at designated "key-point" centers where air raid alerts, transmitted from Air Defense Control Centers, may be received at any time for dissemination to civil defense personnel and to the general public throughout the warning areas.

Several years of careful planning has gone into the formulation of this single observation activity. It has been most carefully planned to avoid inroads upon a manpower pool that could very easily be overtaxed in a war-time period. Many more months will be required to complete its organization and the training of its individual participants. This explains the expediency—in fact the necessity—for its present establishment and maintenance on a stand-by basis. Its function in conjunction with the radar screen will be to make the tactical air defense possible. In addition, it will furnish information on which a civilian air raid warning can be based. As a tentative measure, the military is installing effective communication arrangements whereby responsible civil officials in each of the 48 states can be given the same early warning available to military commanders, in the event of any attack by air. This warning system can be quickly expanded to a complete public warning system when the protective services of the civil system achieve a capacity for taking effective action.

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PACKING INCENDIARY

(Continued from page 21)

the "collar" of one fitted into the other. This seal was maintained by an especially designed clamp which covered the gasket and kept the two drums in compression against it.

The quality of the moisture-vaporproof seal obtained with this container, and its lower unit cost, overcame the disadvantage of its slightly larger cube. It was adopted as standard.

Unfortunately, however, the final solution had not yet been attained. The stocks of 8% moisture wood for interior bracing were soon exhausted, and sufficient plywood to augment the supply was not available. As a result, damp wood was finding its way into the packs. This was subsequently creating a high humidity condition within the moistureproof drums.

When only slight amounts of wet lumber having over 8% moisture content were employed, it was possible to rectify the condition by the use of several pounds of silica gel or equivalent dehydrating agent. This solution would have been feasible in view of the somewhat increased availability of dehydrating agents at that time. However, the added weight and expense were such as to make the practice questionable. Furthermore, the use of continually wetter and wetter lumber, which became imperative in order to maintain production schedules, created demands for silica gel that were once more impossible to fulfill. Also, the additional weight and expense were becoming intolerable.

The development of a new type of wood-free interior bracing for clusters packed in steel drums therefore became mandatory. Because of the fragility of the cluster tail, the ease with which the true flight of the cluster was ruined by misaligning of parts, and the ease and rapidity with which it was essential that unpacking of each cluster be accomplished in the field, the solution of this problem was not simple.

The physical success of the wood braces had been in part due to the floating type suspension of the bomb cluster within the wood bracing, and in part due to the resilient nature of wood. When less resilient materials were substituted, the shock of the impact was directly transferred to the cluster with resultant damage.

Many methods of accomplishing the necessary bracing were tried, and numerous tests were made. Several possible solutions, such as the synthetic rubber, steel pipe and twin steel girdle braces, as shown in Figure 8, were developed to the point where satisfactory protection was obtained, but these were mostly impractical from a production viewpoint. Eventually, however, a system somewhat similar to that shown in Figure 8, but using three paper rolling hoops in lieu of the many rubber braces, and only one steel girdle, provided an answer to the final major problem of incendiary bomb cluster packing. However its adoption as the approved design was never consummated by production since cluster manufacture was terminated at that point with the cessation of hostilities.

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Schedule changes, on institution of Daylight Saving Time prevent our giving exact flight schedule.

BOSTON—
Fare to Norfolk—one way $38.18—round trip $72.69

ST. LOUIS—
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NEW YORK—
Fare to Norfolk—one way $26.85—round trip $51.15

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Travel Digest—AFCA Annual Meeting. All times quoted are *"Standard Time"*

RAIL SCHEDULES FROM EASTERN POINTS TO VIRGINIA BEACH, VIRGINIA, VIA CAPE CHARLES, VIRGINIA

Lv. 3:00 PM (South Sta.)	Boston	(New Haven RR)	12:55 PM	2:25 PM
Ar. 7:20 PM (Penn Sta.)	New York	(Grand Central)	8:00 AM	10:00 AM
Lv. 9:00 PM (Penn Sta.)	New York	(Penn RR)	Ar. 7:30 AM	
Lv. 11:10 PM (30th St.)	Philadelphia	(Penn RR)	Ar. 6:15 AM	
Ar. 6:00 AM	Cape Charles, Va.		Lv. 11:25 PM	
Lv. 6:55 AM (Ferry)	Cape Charles, Va.		Ar. 10:35 PM	
Ar. 9:45 AM (Ferry)	Norfolk		Lv. 7:45 PM	
Lv. 10:00 AM (NS Terminal)	Norfolk	(Nflk-Sou Bus Corp	Ar. 7:26 PM	
Ar. 11:00 AM (Cavalier Hotel)	Virginia Beach.		Lv. 6:26 PM	

Daily sleeping cars operated in both directions between New York, Philadelphia and Cape Charles.

RAIL SCHEDULES FROM EASTERN POINTS TO VIRGINIA BEACH, VIRGINIA, VIA WASHINGTON AND RICHMOND, VIRGINIA

Lv. 6:00 PM (South Sta.)	Boston	(New Haven RR)	Ar. 12:55 PM	2:25 PM
Ar. 11:00 PM (Penn Sta.)	New York	(Grand Central)	Lv. 8:00 AM	10:00 AM
Lv. 12:30 AM[1] (Penn Sta.)	New York	(Penn RR)	Ar. 6:25 AM	
Lv. 12:55 AM[2] (Broad St.)	Philadelphia	(Penn RR)	Ar. 5:35 AM[3]	
Lv. 8:30 AM (Broad St.)	Richmond	(ACL Ry)	Lv. 10:40 PM	
Ar. 10:55 AM (Union Sta.)	Norfolk	(N&W Ry)	Lv. 7:35 PM	
Lv. 11:00 AM (Nflk-Sou Terminal)	Norfolk	(Nflk-Sou Bus Corp)	Lv. 7:26 PM	
Ar. 12:00 NN (Cavalier Hotel)	Virginia Beach.		Lv. 6:25 PM	

Daily sleeping cars operated in both directions between New York and Norfolk, and daily, except Sunday mornings, southbound and Saturdays northbound between Philadelphia and Richmond.
(1) Sleepers open 10:30 PM weekdays, 11:00 PM Sundays.
(2) Sleepers open 11:00 PM.
(3) Sleepers parked until 8:00 AM.

RAIL SCHEDULES FROM WESTERN POINTS TO VIRGINIA BEACH, VIRGINIA, VIA CHESAPEAKE AND OHIO RAILWAY

Lv. 9:20 AM (Union Sta.)	St. Louis	(NYC)	Ar. 3:50 PM	11:00 PM
Lv. 9:30 AM (Central Sta.)	Chicago	(NYC)	Ar. 2:50 PM	8:35 PM
Lv. 1:50 PM (Union Sta.)	Indianapolis	(NYC)	Ar. 10:35 AM	4:30 PM
Lv. 1:50 PM (Central Sta.)	Louisville	(C&O)	Ar. 10:30 AM	4:00 PM
Lv. 6:15 PM (Union Terminal)	Cincinnati	(C&O)	Ar. 8:30 AM	2:05 PM
Ar. 11:45 AM (Foot of Brooke)	Norfolk	(C&O)	Lv. 2:20 PM	6:45 PM
Lv. 12:00 NN (NS Terminal)	Norfolk	(Nflk-Sou Bus Corp)	Ar. 1:26 PM	6:26 PM
Ar. 1:00 PM (Cavalier Hotel)	Virginia Beach.		Lv. 12:26 PM	5:26 PM
Lv. 5:45 PM (Fort St.)	Detroit	(C&O)	Ar. 8:35 AM	
Lv. 5:45 PM (Cleveland Terminal)	Cleveland	(NYC)	Ar. 6:55 AM	
Lv. 7:40 PM (Union Sta.)	Toledo	(C&O)	Ar. 6:05 AM	
Lv. 11:00 PM (Union Sta.)	Columbus	(C&O)	Ar. 2:25 AM	
Ar. 5:05 PM (Foot of Brooke)	Norfolk	(C&O)	Lv. 8:25 AM	
Lv. 5:10 PM (NS Terminal)	Norfolk	(NS)	Ar. 8:20 AM	
Ar. 6:10 PM (Cavalier Hotel)	Virginia Beach.		Lv. 7:26 AM	

RAIL SCHEDULES FROM WESTERN POINTS TO VIRGINIA BEACH, VIRGINIA, VIA NORFOLK AND WESTERN RAILWAY

Read Down				Read Up
Lv. 11:30 PM— 1:00 PM (Union Sta.)	Chicago	(Penn RR)	Ar. 6:40 AM-	2:50 PM
Ar. 7:40 AM— 8:40 PM (Union Sta.)	Cincinnati		Lv. 11:35 PM-	9:10 AM
Lv. 8:20 AM—10:20 PM (Union Sta.)	Cincinnati	(N&W)	Ar. 10:45 PM-	8:05 AM
Lv. 5:45 PM (Union Term.)	Cleveland	(NYC)	Ar. 6:55 AM-	11:15 AM
Ar. 9:05 PM (Union Sta.)	Columbus		Lv. 3:30 AM-	8:00 AM
Lv. 10:15 PM (Union Sta.)	Columbus	(N&W)	Ar. 10:45 PM-	7:50 AM
Ar. 11:55 PM— 4:05 PM (Union Sta.)	Norfolk		Lv. 7:00 AM-	2:40 PM
Lv. 12:00 AM— 4:10 PM (NS Term.)	Norfolk	(Nflk-Sou Bus Corp)	Ar. 6:26 AM-	2:26 PM
Ar. 12:45 AM— 5:10 PM (Cavalier Hotel)	Virginia Beach.		Lv. 5:26 AM-	1:26 PM

OLD BAY LINE

STEAMER SCHEDULES BETWEEN WASHINGTON, BALTIMORE AND NORFOLK, VIRGINIA

Read Down				Read Up
Lv. 5:30 PM (7th & Maine Ave. SW)	Washington	(Old Bay Line)	Ar. 6:00 AM	
Ar. 7:00 AM (Foot of W. Main St)	Norfolk		Lv. 5:00 PM	
Lv. 8:00 AM (N.S. Terminal)	Norfolk	(Norfolk Southern)	Ar. 4:26 PM	
Ar. 9:00 AM (Cavalier Hotel)	Virginia Beach.		Lv. 3:26 PM	
Lv. 5:30 PM (Light St., foot of Barre)	Baltimore	(Old Bay Line)	Ar. 5:30 AM*	
Ar. 5:30 AM* (Foot of W. Main St.)	Norfolk		Lv. 5:30 PM	
Lv. 7:00 AM (NS Terminal)	Norfolk	(Norfolk Southern)	Ar. 4:26 PM	
Ar. 8:00 AM (Cavalier Hotel)	Virginia Beach.		Lv. 3:26 PM	

*Sleep until 6:30 AM.

Sailings from and to Baltimore on daily basis; from Washington on even dates in May, odd dates in June—from Norfolk to Washington on odd dates in May and even dates in June.

By plane, train, truck . . . by boat and barge . . . by nearly every type of transportation, Dow chemicals move across the nation. There are weed killers for the prairies, insecticides for the almond and fruit growers in California, epsom salt for the tanneries in Massachusetts, caustic soda for the paper mills of Washington and soil fumigants for the truck gardens of Florida. These are but a few of more than five hundred Dow chemicals serving American industry and agriculture.

A well-organized sales and distribution system is required to move so varied an output of chemicals into a multitude of major industries from coast to coast. At Dow, this complex distribution problem is solved by strategically locating plants, branch offices, and warehouses near the nation's production centers. In many instances, the much-needed material can be shipped overnight from Dow to processing plants in the vicinity.

This close relationship to industry results from Dow's progress throughout the years in production, sales and distribution of chemicals "indispensable to industry and agriculture".

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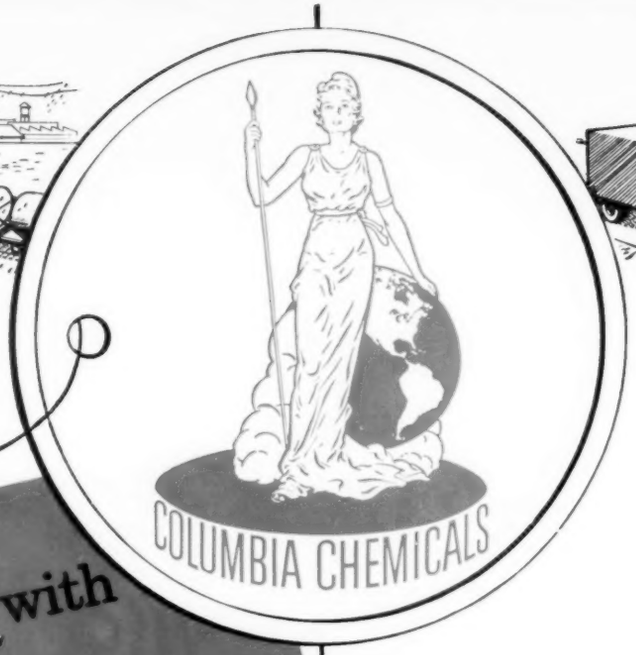
New York • Boston • Philadelphia • Washington • Atlanta • Cleveland • Detroit
Chicago • St. Louis • Houston • San Francisco • Los Angeles • Seattle
Dow Chemical of Canada, Limited, Toronto, Canada

DOW

CHEMICALS

INDISPENSABLE TO INDUSTRY AND AGRICULTURE



Always CHECK with COLUMBIA for your Chemical needs

Looking beyond the price tag, you'll find it advantageous to check Columbia for alkalies, chlorine and related chemicals. The consistent high quality of Columbia products is backed by Columbia facilities and services that should be important considerations in your chemical buying. Pittsburgh Plate Glass Company, Columbia Chemical Division, Fifth at Bellefield, Pittsburgh 13, Pa.

COLUMBIA OFFERS THESE ADVANTAGES

- Conveniently located plants
- Adequate production capacity
- Meticulous attention to your requirements
- Speedy delivery
- Technical service
- Trained, skilled personnel
- Over a half-century's experience

SODA ASH
CHLORINE
CAUSTIC SODA
SODIUM BICARBONATE
CALCIUM CHLORIDE
CAUSTIC ASH
MODIFIED SODAS
SODA BRIQUETTES
(Iron Desulphurizer)
PHOSFLAKE
(Bottle Washer)
SILENE EF
(Hydrated Calcium Silicate)
CALCENE T
(Precipitated Calcium Carbonate)
HI-SIL
(Hydrated Silica)
PACIFIC CRYSTALS
(Sodium Sesquicarbonate)
BORAX
PARA-DICHLOROBENZENE
ORTHO-DICHLOROBENZENE
MONO-CHLOROBENZENE
BENZENE HEXACHLORIDE
PERCHLORETHYLENE
MURIATIC ACID

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